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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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Brass and Copper Sheets, Plates, Tubes & Wire, Block Tin, Zinc, Spelter, and Patent Metal	5	Nails	31
Buckets, Oil Cans, Zinc Sheets, Galvanized Iron Sheets, Emery, &c.	6	Overalls and Oil Skin Suits	32
Buffers & Axle Guards for Carriages and Wagons, Wagon Hinges, Barrow Frames, &c.	7	Oils (Burning, Lubricating, &c.)	33
Canvas	8	Plates (Steel Boiler), Steel Forgings, Fish Plate Liners, Cast Steel Engine and Tender Wheel Centres, Roof Bars, and Mild Steel Plates, Bars, Angles, Tees, and Channels	34
Castings (Ordinary Iron), Firebars, Forgings, Crucibles, Cylinders, & Buffer Stops	9	Rope, Twine, Flax, and Hemp Gaskin	35
Cement, Plaster of Paris, Slates, Glazed Ware Pipes, Fire Bricks, Tiles, &c.	10	Screws (Iron & Brass), Split Pins, &c.	36
Chain	11	Signalling Materials	37
Colours, &c. (ground in oil and dry) and Hall's Distemper, Wall Paper, &c.	12	Springs for Engines, Carriages, Wagons, &c.	38
Drysalteries	13	Tin Plates	39
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Tenders, made out on the Company's Forms, should be delivered, under sealed cover endorsed "Tender for Stores," to the undersigned, not later than 10 a.m. on the 1st November, 1917.

The Directors do not bind themselves to accept the lowest or any Tender.

T. MORRISON, Secretary.
Secretary's Office, Amiens Street Terminus, Dublin, 4th October, 1917. H 967

THE SOUTH INDIAN RAILWAY COMPANY, LIMITED,
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STEEL TYRES for Locomotive and Rolling Stock.

Specifications and forms of Tender may be obtained at the Company's Offices.

Tenders addressed to the Chairman and Directors of the South Indian Railway Company, Limited, marked "Tender for Steel Tyres for Locomotives and Rolling Stock," must be left at the Offices of the Company not later than one o'clock on Monday, the 15th October, 1917.

The Company is not bound to accept the lowest or any Tender.

A charge, which will not be returned, will be made of 20/- for each copy of the Specification.

Copies of the drawings may be obtained on payment at the Office of ROBERT WHITE, Esq., M.Inst.C.E., Consulting Engineer to the Company, 3, Victoria Street Westminster, S.W. 1.
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3rd October, 1917. J 2

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Tenders must be delivered before Eleven a.m. on Friday, 12th October, 1917, addressed to The Secretary, H.M. Office of Works, &c., Storey's Gate, London, S.W. 1, and endorsed "Tender for Steam Tubes and Fittings."
H.M. Office of Works, &c.,
4th October, 1917, H 968

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FREDK. HORNER,
Education Office, Coventry. Secretary.
27th September, 1917. H 947

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good engineering training, able to design the mechanical portion of electric machinery; well versed in calculation of stresses, sizes of shafts, gearing, &c., and possessing a knowledge of shop methods. State full particulars, including age, qualifications and salary expected. No person already engaged on Government work will be employed.—Apply to nearest EMPLOYMENT EXCHANGE, mentioning this Journal and H 942.

Wanted, Immediately, Two

or Three Experienced DRAUGHTSMEN. Good detailers with tool experience for important Government work. Salary according to experience. No one already on Government work will be engaged.—Apply to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and H 967.

Wanted, an Experienced

DRAUGHTSMAN, used to small internal combustion engines. No person already on Government work will be engaged.—Apply nearest EMPLOYMENT EXCHANGE, mentioning this Journal and A 3780. H 974

Draughtsmen, Mechanical.—

Several First-class DRAUGHTSMEN REQUIRED for the design department of a large aircraft concern. Applicants preferred with practical experience, not necessarily on aircraft.—Application to be made to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 3788. No person already on Government work will be engaged. H 976

Required by Engineering

Works, S.E. London, DRAUGHTSMAN (Mechanical or Marine); also Drawing Office CLERK. Junior applicants must have had several years' experience. No applicants residing outside radius of ten miles or already employed on Government work can be engaged.—Write, stating age, experience and salary required, to H 986, Offices of ENGINEERING.

THE ARRANGEMENT OF MACHINE SHOPS.—No. XIX.

By Joseph Horner.

In the last article we considered the influence which the nature of the work to be done has on the determination of the most suitable lay-out of the machine tools, and of the auxiliary services that are the most appropriate. In the present article it is proposed to discuss the manner in which the designs of the machines themselves, and the systems according to which they are associated and operated, affect the character of the services. The two points are closely identified.

The changes which are constantly occurring in the designs of the later types of machine tools are either of a radical kind or they are secondary in character—mere modifications of standard designs. One remarkable point of interest is the large place which is now filled by those tools which are of an absolutely special character—machines designed to perform operations that are of a more or less restricted nature. Such machines are the direct result of the present high specialisation in production. Around each department of manufacture have grown, and are growing ever more rapidly, groups and types of machines that are characterised by some well-marked variations from previously crystallised precedents, or else by their wholly novel aspects—types the growth of which has been fostered and nurtured by the presence of unusual environments, by changed conditions, by the new vitalities that are in intense movement at the present time.

Machines are no longer valued by the enduring expectations of a natural life or by their capabilities of resistance to wear—that method of valuation has been relegated to the dead—though very recent—past. The real value of a new machine is estimated now by its ability to deal with the demands of the present time, or of the few years immediately succeeding. Its permanence in favour is not secured absolutely, but is always in jeopardy. To-morrow some novel and unanticipated development may threaten it with swift supersession—may bring it within sight of a rivalry that will shortly relegate it to the scrap heap long ere the normal period for readjustments and repairs can arrive.

Various occurrences and movements of magnitude may contribute to render excellent machine tools antiquated in the sense of being no longer sources of profit, and this long before they manifest marked signs of wear. Conditions arise which result from changed views respecting methods of tooling. Others are caused directly by the advent of new industries. Both are largely responsible for many alterations in the designs of the later machine tools. Both have been extremely active during recent years. Each aspect would offer a tempting field for a more extensive treatment than can be ventured on in connection with the present subject. Always the problem for solution comes back to that of the relative cost of the work done on machines of different kinds. One of the teachings of the machine shop of to-day is that of "other ways" of producing like results. Managers have larger resources at their command, more alternatives, a much wider range of selection of tools and appliances than their predecessors enjoyed. Naturally their resourcefulness has developed amid broader horizons. They have learned to abandon the narrow grooves of use and custom and to adopt methods of tooling which could not have been entertained when alternatives were limited as compared with those which are now available.

Thus there are now several diverse ways of producing cylindrical forms, or plane surfaces of irregular outlines—the production of which once entailed much tedious correction by hand work and templet. Such are now machined readily with a sufficiently close approach to accuracy, and with uniformity, in any number of pieces. The milling and the grinding machines have changed practice profoundly, and have taken vast quantities of work away from other tools, performing it, if not always with finer results, yet with more rapidity than the rival machines were capable of accomplishing. Output is multiplied by the employment of multi-spindle machines, as drills, boring machines and some turret lathes, in which from four to half a dozen spindles are carried. It is also increased by the grouping of several tools in some modified designs of common lathes, and in many box tools in turret lathes, in vertical boring and turning mills carrying several tools, in crank and cam turning and grinding machines, and so on. In the selection of machines and methods immemorial practice does not count, but the ultimate results rather are visualised, and methods are subordinated to them. Times are carefully collated, with the object of saving minutes or even seconds. The expense of fixtures, and even the high cost of additional machines, are brought into their true perspective instead of being allowed to bar the way to the real economies of production. These changes are revolutionary in character, and they would impress the mind more powerfully than they do but for the fact that they are growing familiar to the generation that is being trained in them. But the older men, who witness the inevitable displacement of handicraft in which they were trained and exercised, marvel at the banishment of individual initiative in machine-tool methods by the automatic and semi-automatic systems, the cards, and the routing methods.

Changes which arise directly out of the advent of new industries are even more prominent than are those that are consequent on divergent views of methods of tooling. The growth of new manufactures in a market already crowded with rival firms compels a keen inspection of methods which afford something more than a merely interesting study in alternative ways. Their adoption, or neglect, in their ultimate results may involve success, or loss, or even total failure. Not only are differences in times occupied by operations in question, but limits or degrees of inaccuracy are involved. Sometimes the attainment of the results desired will entail a larger expenditure of time, in others less, perhaps very much less. But the ultimate issue is the thing that matters. The conditions that are imposed, the results to be achieved, control the methods to be adopted.

The newer industries which are exercising most influence in controlling the work of the machine shop are chiefly those that are concerned with the manufacture of all kinds of internal-combustion engines, the manufacture of steam turbines, that of electrical machinery, and, now partly overshadowing these, of munitions of war, which includes mechanisms of many kinds made in vast quantities, many articles being ordered by the hundred thousand. For each of these many highly specialised tools, many absolutely unique designs of machines, are employed in addition to large numbers of modified types of the kinds that are regularly standardised. The problems which have been exercising the manufacturers of motor engines and vehicles and aeroplane details have had to be faced under greater difficulties by the firms who have been engaged in munition work.

One of the remarkable phases of the solution of the problem is the enormous development of what are termed the "single-purpose" machines, or those which are specialised to the last degree. Many of these only perform one operation, some include two or more operations which are identical or allied in character. Equally striking has been the effect of the extensive employment of fixtures and of jigs, and, again, the general use of the tools of high-speed steel. The influences which these three modern movements have on an accelerated output, and, in consequence, on the services of the machine tools, may be noted briefly.

The single purpose machines are big developments of an earlier movement. Their growth has been immensely quickened and favoured by the intensive production of munitions. The problem of how to secure the most rapid output has been the paramount one, and any tools, however novel in design and without precedent, that might help to gain this end have been welcomed. These machines are justifying their existence because they increase output by subdivision of tasks, and because they enable the large contingent of unskilled and semi-trained labour which the war has attracted to the shops to be utilised. This movement, which, though not new, has in its swift growth assumed the aspect of a novel phenomenon, is greatly exercising the judgment of those who have to accommodate shop arrangements to changed conditions. One might enumerate more than a hundred new designs of this class, the products of the last three years, for dealing with munitions alone, to perform only one or two, or a few, related tasks.

The influence which these single-purpose tools are exercising will not cease with the termination of the war. The question of the position which they may occupy in the future is of less importance than that of the retention or the abandonment of the system of which they are an essential element. Many of these machines, and others, embodiments of the same methods, might be readily enlisted in new services in the intensive industrial war that must supervene. They are essential if the dilution of labour is to be retained. The principal machines the work of which has been encroached on by the single-purpose machines are the lathes, followed closely by that of the drills. A few observations on the first-named will show why the single-purpose machines are, in the opinion of many competent judges, to be preferred to the more complicated general-purpose designs.

At the commencement of the war there arose a huge demand for common turret lathes, which the supply was inadequate to meet. It was rightly believed that the possession of these would enable an immense output to be secured. But two requirements are essential if the best results are to be secured from such lathes—a supply of skilled tool makers and tool setters, and operators who have acquired some experience in their working. The supply of each of these requirements proving insufficient for the abnormal demands made, afforded the opportunity and emphasised the necessity for the introduction of the single-purpose machines. These are vastly cheaper to produce than turret lathes are, and they exact the minimum amount of tool setting, and can be operated by new attendants after a very little instruction.

Although turret lathes are automatic or semi-automatic in their movements, an operator who is neglectful or insufficiently experienced may easily allow tools to become slightly displaced or damaged, and by continuing to use them while in these conditions, spoil a considerable volume of work before the gaugers detect the fact. Especially is this the case with the more elaborated boxes of tools that are fitted with slides, setting-up screws, tightening screws, and often with multiple tools. The more numerous these fittings are, the more liable is trouble to result when a neglectful, inattentive or half-trained man is in charge. Another fact to be observed is that the time spent in preparing and setting up batteries of tools and the fixtures or boxes in which they are held is a large item, since many trials may have to be made before everything is quite ship-shape. This contrasts strongly with the simplicity of the equipment of the single-purpose machines.

Another aspect which concerns turret-lathe work that may not be neglected when comparisons are being made is this. In order that the lathe shall be worked at its fullest efficiency all the tools must complete their performances in a single cycle, or often, in small pieces, two cycles may be worked off in one revolution of the turret. But in making up combinations of tools, the speed is set by that of the operation which occupies the longest period, and the others lag. The multiple-spindle automatics are machines of general utility which have been pressed very largely into the service of shell work by the employment of special adaptations of tools. They labour under the same kind of disability which affects the ordinary turret lathes, namely, that the length of the major operation sets the pace for the others. Because of these facts the single-purpose machines have often been preferred to the turret lathes, even though some re-chucking and resetting are entailed.

And thus, since every single item in a piece of work—a motor part, an engine detail, a shell section—may be the subject of alternative treatment, the individual selection of methods must ultimately be determined by the character of the machine tools which happen to be already available, or which can be obtained with the least delay; or,

THE ARRANGEMENT OF MACHINE SHOPS.

THE WORKS OF MESSRS. G. AND J. WEIR, LIMITED, ENGINEERS, CATHCART, GLASGOW.

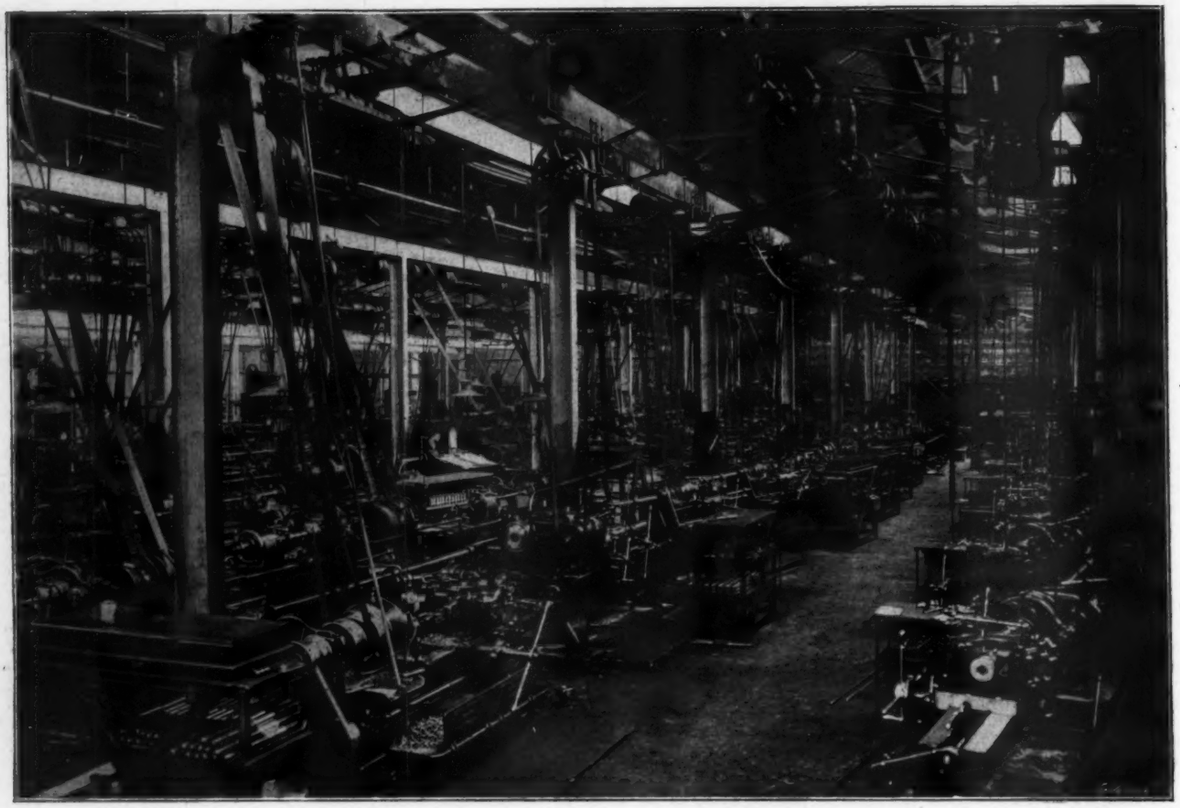


Fig. 176. View in Turning Machine Shop.

if the choice is not limited, by those which are most adaptable to the class of labour to be obtained and to the production of a maximum output. The solution bristles with difficulties. Though there are certain tools that are the best for the performance of certain operations carried through under favourable conditions, and which are regularly employed in normal times, at present many tools have to be utilised which have not been selected for such work before, and would hardly be used now if the regulation designs could be obtained. The most dominant resulting fact now is that of minute subdivision of tasks between the simpler machines. The adoption of this practice entails the necessary completion of different but related operations within a basis time in order that all the parts of an article—a unit or a complete mechanism—shall be completed simultaneously. This involves increased and specialised machine services, and requires the establishment of stores, and of clerical work for dealing with the large accumulations of finished parts.

Fixtures and jigs may not appear to have more than a casual relation to shop arrangements, yet a very pronounced influence thereon is exercised by them through the machine tools on which they are employed. So intimately are these related, that the lay-out of the tools and their services, which may have been above the reach of serious criticism in the absence of fixtures and jigs, may have to be reconsidered when the employment of these has become established. They react on the tool arrangements, on the transport, and on the storage. The jig, but much more especially the fixture when most highly developed, dominates to a great extent the machine tool. This is a cogent reason why it must often happen that tools of dissimilar types will be placed adjacent, solely in order to

Fig. 178. Stores of Turned Parts of Pumps and Stock Bars.

THE ARRANGEMENT OF MACHINE SHOPS.

THE WORKS OF MESSRS. G. AND J. WEIR, LIMITED, ENGINEERS, CATHCART, GLASGOW.

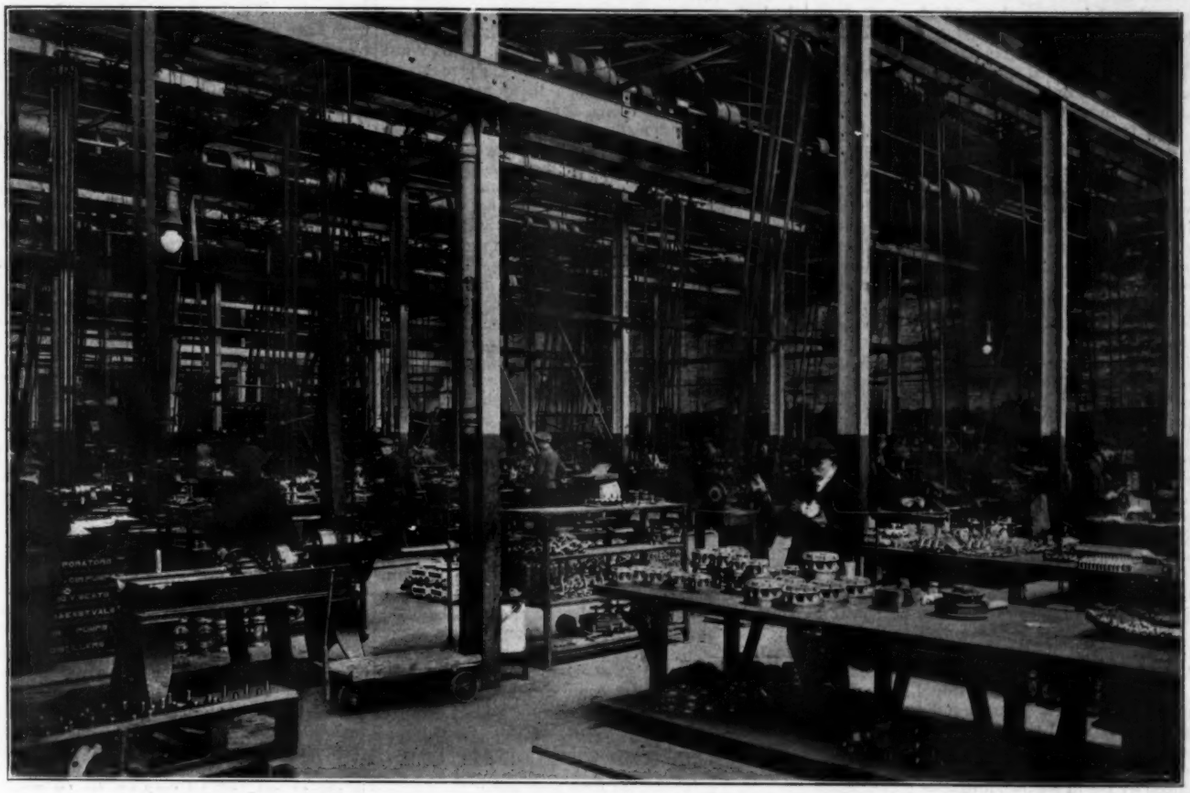


Fig. 177. View in Turning Machine Shop.

Fig. 179. Store with Bins for Finished Parts.

facilitate the transfer of the fixture, with its enclosed piece of work, from one to the other with the least delay. Thus milling and drilling machines may be contiguous; or planer, shaper and drill; or vertical boring machines with drilling machines. The conditions are different from those that exist where the work has to be adjusted and clamped directly on machine tables. Being located once for all in the fixture, it, with its enclosed piece, is moved and set rapidly as a single self-contained unit upon the machine tools between which the total operations are apportioned, and which are often simplified to the last degree. To so great an extent is this subdivision of functions carried that the transfer made from one machine to another is not always that to one of another kind. The scheme may include roughing on one and finishing on another of the same character. The boring of automobile cylinders is frequently divided thus. Or the division may be that of boring on one machine, followed by finish-grinding on another. Or between crank turning and crank grinding. The turning of the pins of a crankshaft is even divided between two lathes, one dealing with two adjacent pins, the other with the two end ones. Gear wheel teeth are frequently roughed in one machine, but finished in another of a different design, being one of high precision. Such examples might be multiplied.

These very minute subdivisions of tasks, which constantly increase in number and variety, all influence and tend to complicate the question of the best possible arrangements and services of machine tools. In some degree they are favourable to the adoption of the individual motor drive, since tools —those of heavy designs, which require special deep foundations excepted—can be moved into fresh positions when desirable without regard to the location of line shafting. We appear to have arrived at a period when the fixture and the machine are entering on a struggle for precedence. Fixtures become increasingly comprehensive, vastly more complicated, their elements are standardised. Any article which is of medium dimensions, if required in sufficient quantities, is now tooled by the assistance rendered by the jig or the fixture, or by means of a combination of the two.

Tools of high-speed steel have exercised an influence on the service of machines, because output is trebled or quadrupled when the carbon tools are displaced. The result is that in order to avoid

congestion of work and of cuttings the inter-machine spaces and gangway widths must be correspondingly larger than sufficed when the old conditions prevailed. Even with the most efficient systems of transport, work will soon accumulate on stands and floor. The high-speed products supplement and increase those which result from the minute subdivision of tooling operations in single-purpose machines and in fixtures.

A store for finished parts has always been necessary in all except the very small shops. But with the enormous increases in production which have been fostered by the movements just enumerated, the importance of this department has been vastly magnified. The separation of parts is now more desirable, more minute classification is involved, and considerable clerical work is entailed. This is a department kept distinct from the general stores for elements and articles which are largely bought outside—stock bolts, nuts, pins, screws, cotters, oils, abrasive materials, and the hundred other items which combine to make up the elements of mechanisms, or that are used in shop processes. It includes only the pieces of work that are rough or finished, the single parts, or the completed units that are prepared by the machinists, the assemblers or the fitters. These are entered into stores, duly recorded, and passed out to the men who build up the machines or mechanisms. Under the interchangeable system, and in the manufacture of specialities, the stores grow to very large proportions. It is necessary to maintain a due balance between the parts which are stocked and the machines to be completed. If stocks of some parts are running low while others are well filled, the balance must be restored. This does not imply that the parts stored must be multiples of finished machines. That is rarely carried out, partly from lack of storage facilities to accommodate the more massive parts, and partly to permit of making variations in some major dimensions to accommodate the requirements of individual purchasers. The minor details, parts of medium dimensions, and the smaller completed units are made and stored, and are not subject to alteration excepting in consequence of the gradual improvements which are introduced by the firm's own initiative; very many of these units serve for more than one machine or mechanism, hence they are manufactured in larger proportional numbers. In the case of an extensive works one storeroom will not suffice. And dimensions increase as the output of the machines grows. The illustrations which accompany the present article will indicate the magnitude of the present-day stores for finished work, and the manner in which they are fed by the shops.

The two views, Figs. 176 and 177, on pages 350 and 351, show the turneries and machine shops of Messrs. G. and J. Weir, Limited, of Cathcart, Glasgow. The work, as it is finished, is placed on stands adjacent to the lathes or machines, and thence taken to tables where it is gauged by the viewers, and afterwards passed into stores. The stands, it will be noticed, have ends mostly of cast-iron, though some have legs of iron tubes or rods. They carry tiers of shelves, of wood, and have diagonal bracings. Hand trucks convey the parts along the smooth floor. As the articles are only of moderate weight, no crane service is necessary.

The store, in which large quantities of turned parts for pump work are stored, and also the stock bars, is seen in Fig. 178. All these are carried on stands with cantilever-arm supports. The ends are castings, the arms are of rolled angle sections. Another store, Fig. 179, is provided with bins on one side for turned parts and miscellaneous completed sections, as covers, cocks, bolts, &c., and on the opposite side with substantial wooden racks against which shafts are stood in an inclined position.

The views in Figs. 180 and 181, on Plate XXXII, show departments of the finished stores of Messrs. Marshall, Sons and Co., Limited, of the Britannia Iron Works, Gainsborough. The first is that for engine parts. Governors are seen in the foreground. Behind are rows of pins for small parts, above are bolts, stop valves, connecting rods, eccentric rods. Fig. 181 is a view in the brass store, occupied also by a supply of finished governors in the foreground. Bins contain water and vacuum gauges, taps, cocks, spindles, valves and so forth. Against each bin a card, too, is fixed showing at a glance the name of each part and the number in stock. When numbers run below a stipulated limit, the storekeeper has to inform the shops of the fact.

The succeeding illustrations on Plate XXXIII give views in the new shops of Messrs. H. W. Ward and Co., Limited, of Birmingham. The firm retains the Lionel-street Works, but these new shops at Bournbrook have become necessary to deal with the increasing demands for capstan and turret lathes. The buildings are constructed on the parallel bay system. The machine-tool section comprises seven bays, each 150 ft. long and 20 ft. wide. Grouped at one end are the inspection department, the finished part store, and the tool store. The machines are grouped in sections, and the heavier ones are nearest the doors. The groups include heavy lathes, a department for polishing and buffing, flat turret lathes, light capstan lathes, pulley turning, a gear-cutting section, a lead screw section, a milling department, and sections for grinding and for planing. Four bays are devoted to fitting, assembling and erecting.

The view in Fig. 182 is taken in the flat turret lathe department for bar work. It is plentifully provided with stands for finished pieces, which carry trays of vee-section, that confine the articles so that they do not tumble off when piled up. In Fig. 183 the method of assembling lathe headstocks is seen. These are erected complete on stands, and each one is run and tested by belt before it is passed to the lathe builders. The driving is done from a portable stand built of angle sections. This stand carries driving pulleys at the top, the power for which is derived from an electric motor in the base. Fig. 184 shows the inspection room, where every detail is finally checked before it is passed to the counter of the adjacent store seen in Fig. 185. These new works were commenced not long before the war, and they occupy a site of about 3½ acres.

THE IRON AND STEEL INSTITUTE.

(*Concluded from page* 326.)

On the members reassembling on Friday morning, September 21, the first paper taken was the one on

The Failure of Boiler Plates in Service, and Investigations of the Stresses that Occur in Riveted Joints,

by Mr. E. B. Wolff, Dr.-Engr., Bussum, Holland. It was read in abstract by the secretary. We reproduced it in full on page 326 of our last issue.

The discussion was opened by Mr. Stromeyer, who said he found the paper extremely interesting; it came at an opportune moment and confirmed another very similar case which had come under his notice. Unfortunately the investigations by the author threw no light upon the actual cause of the explosion referred to, and he could not say he was very satisfied with the details given; but the case was surrounded with very much mystery. The name of the steamer on which the explosion occurred was well known. Some plates were sent to him (Mr. Stromeyer), and he had found some nitrogen in them; he thought the author should have taken the nitrogen into account. He (Mr. Stromeyer) understood that the steel was basic steel; the author had said that acid steel plates failed in the same way. The author should have made comparative tests of both acid and basic steel plates. He (the speaker) had found no failure of acid steel shell plates of marine boilers when, seventeen years ago, he was at Lloyd's. In land boilers he had found plates of basic steel which had failed. He showed a drawing of a boiler 8 ft. long and 8 ft. 6 in. in diameter, built in 1906; in 1916 the manufacturer was informed that steam was escaping from it and was damaging some material stored in the loft above. Cracks were found in the boiler at the riveting, extending over a length of 5 ft. 6 in., and the reason why the boiler did not explode was a mystery. Mr. Stromeyer obtained permission from his association to purchase a part of the boiler, or the whole of it, but the owner refused. He then offered to send men to cut out the plate, but again without success. The only material he finally obtained was a small scrap out of the crack. The name of the steel makers was that of a firm who only manufacture acid steel. But the works owning the boiler concentrated caustic liquor, and it was possible that some caustic soda got into the boiler feed water. The accident in the case he referred to may have been due to caustic soda, and it was possible that this acted more on one class of steel than on another. He (the speaker) had further mentioned before, from experiments he had made, that the caustic soda seemed to affect steel only if it was in a stressed condition. He showed on the blackboard where cracks usually occurred and developed in a tube plate; where the material was stretched and not compressed was the part at which the damage took place. He had put rings differently treated mechanically into a solution, and only those that were in tension showed brittleness. The effect of the caustic soda travelled right through the metal. Professor Heyn, of Berlin, had said he had not obtained the same results; the results obtained by the author were similar to those of Professor Heyn, and different from his own (Mr. Stromeyer's). The author, in the last paragraph of his paper, stated that the same kind of cracks he referred to were found by Mr. Merica in different kinds of boilers; that the cracks described by him had occurred not only in the water space, but also in the steam space; and that as the boilers cracked after being in service for one or more years, recovery of the material from the effect of the alkali should have taken place long before the cracks started. Mr. Stromeyer asked whether the author dosed his boilers with alkali; he thought, he added, that the author was probably using some patent boiler fluid to stop corrosion, and he hoped he would state in his reply whether this was so, and state also whether the boiler was built of acid steel plates.

Mr. J. T. Milton, who followed, said that the case referred to by the author was a well-known case. The boiler was built in 1906, and burst in 1908; it was about the only marine boiler which had burst with disastrous effects in use. As an unfit shell plate failing through an unknown cause, it was the only one, and there were at least 50,000 boilers in use at sea, of all ages up to 20 years. Mr. Stromeyer had intimated that there was no trouble with acid steel, and that perhaps basic steel was not so reliable as acid. He (the speaker) was not sure whether the boiler in question was of acid steel. Basic steel boilers were made in Holland by a firm of great repute, and he was sure all the required care was given in the manufacture throughout. The steel was made by a German firm who manufacture more basic steel than any other firm on the Continent. One plate was returned to Holland, and he (the speaker) saw it, and noticed that all the rivet holes had many cracks. After examination in Holland no reason was found for these cracks. Here Mr. Milton added as a parenthesis that he had recently seen the results of tests carried out with great care on two specimens which showed excellent results in regard to the elastic limit and went up to the ultimate in tensile stress; one specimen was heat treated in a certain manner and the other in a different manner. When these were tested under impact, one was found extremely brittle and the other ductile. The difference proceeded from the different treatment. In Germany all the boiler plates were annealed after shearing. We did not anneal boiler plates in this country; in fact only one or two British firms had the necessary plant for annealing them. The speaker visited the German works he alluded to and asked to see their annealing furnaces; he found that they had two, one small and one large one. The plates were annealed in batches, many at a time, piled one over the other. In annealing plates in that way the middle plates could not get hot until their edges were very hot, and it was at the edges that the plates cracked. It was necessary, therefore, to anneal the plates with care and precision. The plate of the boilers of the Livadia were of acid steel; they were rolled into shape, butted and punched with the rivet holes. They were annealed in batches, and were very brittle between the rivet holes and at the edges. Mr. Stromeyer had suggested that he would rather have acid than basic

steel boiler plates; he would remember that basic steel plates twenty-five years ago were received at Lloyd's without suspicion. There had occurred failures in furnace plates; these were very brittle at the edges and he (the speaker) sent a piece to steel makers of basic steel, asking that it should be analysed; it was not basic, but had been wrongly treated, and after annealing it bent double. On another occasion he had a brittle piece of basic steel which, when annealed, was quite restored. Dr. Rosenhain had investigated the problem, but had he, Mr. Milton asked, investigated with the brittle edges of the plates, for what we had to do was to find out what was wrong with the steel round the edges. Mr. Milton then referred to Mr. S. A. Houghton's paper read before a former meeting of the Institute (see ENGINEERING, vol. xcvii, pages 647 and 662) on the "Failures of Heavy Boiler Shell Plates," and to Mr. D. Colville's not giving reasons for occurrences; but he (the speaker) expressed the belief that the steel makers did not know these reasons. He added that he did not think that one explosion should point to the risk of all boilers exploding, and very many boilers were made of basic open-hearth steel plates. The author had stated that the boiler was oil-fired, and had very rightly concluded that that had nothing to do with the accident. Some Dutch engineers had traced it to the oil-fuel firing which, they contended, raised steam too rapidly and spoiled the steel. When all things were considered, however, the conditions under which the oil-fuel fired boilers worked were better than those attending coal-fired boilers; there were no openings and closings of the furnace door and other disadvantages surrounding the use of coal-fuel fired boilers.

Mr. T. Carlton, of the Board of Trade, said that the subject was of great importance to engineers, whose difficulty was that over 99 per cent. of boilers gave no more trouble than was expected, while occasionally a similar boiler unaccountably failed in parts, without any apparent cause; but when the defective plates were replaced, no further trouble arose. The boiler which failed was not a fair criterion to judge the others by. The Board of Trade had very few failures to record, only two having been reported during the last seven or eight years, and as the cracks occurred in the combustion chambers or furnace seams, no serious consequences had resulted. In both cases the boilers were made by experienced makers who had built hundreds of marine boilers. The designs were not unusual, and all the usual requirements had been carried out during construction. The boilers he referred to were not hard worked, but after two years' service cracks occurred in various seams in the combustion chambers of two of the four main boilers. By the end of the third year new plates were fitted, and no further trouble was experienced after nearly five years' service. In another case the boilers in one of two sister ships developed cracks in the furnace and combustion chamber seams. Four out of the six furnaces were renewed, and the cracks again developed. The rivets were taken out, and the cracks opened in parts $\frac{1}{16}$ in. The cracks were welded, the holes re-bored, and the seams united, and he had not heard of any further trouble, the same boiler pressure being retained. In one instance a piece of plate at the seam could be removed by hand, exposing the sides of the rivets. Serious leakage might have been expected had the crack occurred under full boiler pressure. The inference was that the worst cracking occurred when the plates were cooling down and there was little pressure in the boiler. It was common for combustion chamber and furnace seams to be strained by severe contraction stresses, and for leakage to occur at the rivets and binding edges. Dr. Wolff stated that the average tensional stress was 11 kg. per square millimetre, which he (the speaker) thought was a fairly common stress on many boiler shell plates. Dr. Wolff also said that when the value was trebled, such a high stress was reached that very few alternations sufficed to cause a crack. Eleven kilograms trebled, said Mr. Carlton, equalled 20.9 tons per square inch, and that was at the working pressure. The author also stated that the boiler in question was tested hydraulically, when new, to double the working pressure, and on the same assumption of the stress at the edge of the rivet holes being trebled, the stress would be nearly 42 tons per square inch, or 11 tons above the maximum strength of the plates. He (the speaker) did not see how plates having an ultimate strength of about 30 tons or 31 tons were to resist a stress of 42 tons per square inch.

There were larger holes than rivet holes in boilers, and it was commonly assumed that the larger the hole the greater the stress on the edge of the plate. Some of the manhole openings in boiler shells were 15 in. to 16 in. wide longitudinally in the boiler; these openings were compensated, but the bending stresses due to barrelling at the opening were probably more severe than the bending stresses at the rivet holes, when those holes were covered by inside and outside straps. Although the stress at the edge of the plate was higher in the case of the manhole than the stress at the edge of the rivet hole, they had not had a single case of the failure of a shell plate under stress pressure in any marine boiler during the last twenty years or more. They had no cracks or failure, either, at holes in the shells made to receive boiler mountings, which were several times larger than rivet holes and not compensated. A considerable number of riveted seams had been experimentally tested to destruction, and in nearly every case when the holes were drilled the breaking strength per square inch along the line of perforations exceeded that of the unperforated plate. The strains due to the bending of the shell plates cold, which stretched the outside layers and compressed the inside layers of the plate, were not mentioned, but in many cases the stretch of the outside furnaces might be $\frac{1}{8}$ in. per foot, and that stress appeared to him to be greater than that referred to by Dr. Wolff. Many boilers had been tested to double the working pressure hydraulically; he was not aware of any marine boiler failing at that hydraulic test.

It was difficult to get away from the idea of abnormality of the steel. Metallurgists had been trying for years for tests which would reveal brittleness, and if these tests could be devised, still fewer failures of boiler plates might in the future be recorded. In the diagram, Fig. 7, small isolated lines were shown, and he would like to know whether those lines represented cracks. Isolated cracks would not be expected in normal steel plates so far from the rivet holes when the stress was not above the average. In Fig. 8, showing cracks in a circumferential seam, he asked whether the shell plate was thicker than the end plate, as usual in British practice. If the shell plate were the thicker, and the cracks were in the circumferential direction and not due to longitudinal stresses, he did not see why they should develop in the thicker plate, which was also probably of higher tensile strength.

Dr. Rosenhain said the paper was an interesting one, as also were the views which had been expressed by the speakers. A large amount of work on the influence of holes in material had been carried out by Professor Coker by optical means, and his results had been verified and could be applied with advantage. He was surprised that the stress round large holes was the greater stress. Many cracks did not occur through the rivet holes but at other points. He showed on a sketch on the blackboard cracks between the rivet holes, and also at other places, due to overstrain. The right method of testing was by single-blow or double-blow impact test, to ascertain the quality of the metal. The tensile stress was good, and there was perhaps a rather low elastic limit, but the impact test would be the one to show when a steel was not all that it should be. Blame should be attached to the treatment of steel and not to its manufacture. He thought the reasons had been found to account for a plate which cracked during bending. All plates had banded structures of ferrite and pearlite, and in tensile tests these did not make themselves felt. There was a possible danger, in taking low-carbon steel, cold-rolling it and heating it to a temperature below the critical point, that grain growth may occur, and hence brittleness if the grain growth is carried to a great extent. But in boiler plates the carbon percentage is too high to allow that to take place, provided the carbon be well distributed. When it does occur, there are bands of coarse crystals, and on the material being stressed under expansion and contraction trouble is caused.

Dr. C. H. Desch said he had had experience of the action of caustic soda on an open tank which was under no pressure, and he found that it caused great brittleness. The action of caustic soda was greatest when the steel was overheated locally, and it commenced at those overheated parts, where there occurred complete intercrystalline separation, the metal being opened out. Caustic soda encouraged, as it were, the embrittling action in stretched steel; the steel became brittle under impact.

Dr. Arnold stated that he had listened to the discussion with great interest, and he agreed largely with the views expressed by Dr. Rosenhain, but it was no doubt by a lapse of memory he had said that the laminæ of ferrite surrounded pearlite. Broadly speaking, that was no doubt correct. He (Dr. Arnold) would have expected in boiler plates to find the pearlite over against the edge, and in the strict meaning of the term the middle was ferrite.

Mr. C. H. Ridsdale, in regard to annealing, referred to a series of papers which were read some years ago dealing with the thermal treatment of steel, and said that one point he had brought out was as to brittleness induced by over-annealing. He had dealt with a large number of samples, and had experienced no difficulty in synthetically reproducing extreme brittleness. He thought that the extent to which steel could get brittle by annealing was not sufficiently grasped. He exhibited at the meeting a sample which had parted in the middle, and showed on the blackboard a section $\frac{1}{4}$ in. thick, pointing out the grain growth from outside inwards and the parting of the metal in the centre. The only thing wrong in that particular case was that annealing had been carried out at rather too high a temperature and for rather too long a time. Mr. Ridsdale further added that an outer ring of ferrite was often found after over-annealing.

Mr. J. P. Bedson confirmed what Dr. Rosenhain had said, and showed on the blackboard a peculiar formation in steel bars; after annealing and working them up he had found two sets of crystals, outside large and inside small. The material was tough before annealing, and after annealing perfectly brittle; it broke at the impact test.

The author, on the motion of the chairman, was awarded a hearty vote of thanks for his paper.

Investigation upon a Cast of Acid Open-Hearth Steel.

The next paper was the one having the above title, by Mr. T. D. Morgans and Dr. F. Rogers. It was read in abstract by the former, Dr. Rogers dealing with the microsections. The work which the paper describes was undertaken with a view to determining the general quality and uniformity of the acid open-hearth steel made at the Blaenavon Company's works for the manufacture of open-hearth steel.

The Acid Open-Hearth Process.

The paper having the above title, by Dr. F. Rogers, was then read in abstract by its author. The above two papers were taken together for discussion. The main object of the second paper, said Dr. Rogers, was to give critical consideration to the principal features of the acid open-hearth process which affect the production of a sound clean ingot. Naturally, he added, attention had been mainly centred upon the most predominant of the features, deoxidation. We reproduce both papers in full in the present issue.

The discussion was opened by Mr. Cosmo Johns, and with reference to the first paper he suggested that the authors, dealing with a similar steel, should take a sample immediately before tapping and one at the end of teeming, manganese having been added; he hoped the results they found with these two samples would be given as an addendum to their paper. Mr. Cosmo Johns here indicated that the results were due to the reaction between the manganese in the steel and the iron oxide in the slag, which took place during teeming.

With regard to Dr. Rogers' very interesting paper, he (the speaker) wished to mention a few points

which were not taken into account in the author's rather complex diagram. It was difficult to describe the many physico-chemical changes taking place in the open-hearth furnace, but by taking into account the number of components in action, some idea would be obtained of the problem to be solved. Here the speaker drew on the blackboard a section through a furnace, and pointed out the furnace gases above and the layer of slag covering FeO and MnO, the latter constituent being very important. In regard to the influence of lime, he (the speaker) agreed with the conclusions which had been arrived at by Mr. McCance as to the proper use of lime. The process in the furnace was most complex; at a certain definite temperature equilibrium was established, and if lime was added it had no effect on dead-melting, but it might add to the control of the bath. There was a certain critical temperature in the open-hearth furnace, above which there was an active reaction between the carbon of the bath and the iron oxide in the slag, and below which the reaction occurred slowly or not at all. This temperature required working out. There was also the reaction between the silica in the slag and the carbon in the bath. Dr. Rogers' paper did not mention the surface tension of the liquid steel, and this was a most important point. The surface tensions of liquid metals were well-known; a paper on the subject had been read before the Institute of Metals. The value of the surface tension of the liquid steel was the only method available for showing how far melting had progressed. The workmen knew it well, they had a distinctive name for the effect which they observed, although they did not know the cause. The surface tension, added Mr. Cosmo Johns, afforded a direct proof that iron oxide was dissolved by the metal. The iron oxide was increasing in concentration in the metal, and the effect of the reduced surface tension could be seen. He suggested, in conclusion, that in the physical study of the subject the surface tension should not be overlooked; it was the only practical way of determining dead-melting and was the one used by the melters.

Mr. A. McCance said that the facts expressed in the paper were most interesting as being Dr. Rogers' personal opinion, but he (the speaker) would have preferred him to state the experiments upon which that opinion was based, because experiments could be interpreted in more than one way. Modifying somewhat the former speaker's diagram, Mr. McCance said that $FeO + C = Fe + CO$ was the reaction which took place in the open-hearth furnace. There was a definite concentration of FeO in the slag, and as long as the temperature was constant the ratio of FeO in the steel to the concentration of FeO in the slag was also constant, *i.e.*, the higher the percentage of FeO in the slag, the higher the percentage of FeO in the steel. Using the former speaker's section on the blackboard, Mr. McCance showed that the FeO was in solution in the steel; the carbon and gas were in solution, but during the boiling carbon monoxide was given off, and therefore the steel must be saturated with it. He further stated that C_1, C_2 and C_3 were the concentrates, the mass of the iron, and that $\frac{C_1 \times C_2}{C_3}$ was constant. During the early stages there was a high percentage of FeO in the steel, and therefore to get the balance C_2 must diminish; the reaction took place and the carbon was diminished. Near the end of the operation a balance was more or less obtained, and the lower the concentration of FeO the lower also the concentration of the gases, as then the carbon could be assumed to be constant. On the steel leaving the furnace, the carbon was also constant, as also was the ratio of the ferrous oxide to the amount of gas dissolved. He (the speaker) disagreed with the addition of lime in the early stages, because then the reaction was slowed down.

Mr. McCance concluded by stating that if the temperature was increased, as the heat of reaction was positive the constant K must diminish. If it diminished, an increased temperature meant a decrease of concentration of FeO in the steel, and he did not think Dr. Rogers' Diagram II was correct for that reason.

Dr. W. H. Hatfield entirely shared the point of view that Dr. Rogers' paper was a suggestive one; he thought it a purely theoretical one, insufficiently supported by actual experimental data. The author had made a number of statements and deductions, with all of which he (the speaker) did not agree. He further thought the author had attempted to cover too large a field. The various reactions between the liquid metal and the slag were very complex, but they lent themselves to determination. A large amount of work had already been done in that line, but no reference was made by the author to other investigators, with the exception of Mr. Kilby's paper read in May last. His (the speaker's) view in regard to the reactions in the acid open-hearth furnace were relatively simple as far as the actual operation was concerned. If the carbon was permitted to react in the slag, a position of equilibrium was attained, that was to say, that oxidation took place in the metalloid bath up to a certain percentage, then there was a switch over. In an acid open-hearth furnace, with silicon at about 55 per cent., as the silicon went up in the slag there was a percentage at which silicon and manganese existing as oxide in the slag went back into the bath. It was a fact that there was an acid silicon and an acid manganese being liberated from the slag going back into the bath. This meant that there was then little oxygen in the bath. Steel could be killed adequately by watching the slag and the components of the steel carefully. All good melters went by the viscosity of the slag, and this was determined by the silica contents and the temperature. The addition of lime modified those two factors. A good melter could kill the steel; it was an easy operation. He thought the paper would have been more acceptable had the author given less theory and had enlarged upon the points which could be attacked. In regard to Messrs. Morgans and Rogers' paper, he asked what method had been used in determining the manganese.

Mr. Alleyne Reynolds, who followed, thought the thanks of the Institute should be conveyed to Dr. Rogers, if only for the very nature of his paper. It dealt with the birth of steel, and there was too small a quota of that class of paper read before the Institute. The number of papers on the heat treatment of steel after it was made, and, it might be, wrongly made, was in undue proportion. About twenty years ago, when he (the speaker) had charge of the open-hearth furnaces, crucibles, gun and armour-plate hardening plant at Messrs. Vickers, the facts that came under his notice led him to give attention to various phenomena. Among his conclusions was one to the effect that the acid open-hearth process was more complicated than any other steel-making process. In the basic process, by its very nature, the reciprocation of chemical reactions was prevented. In many writings he had read, steel seemed to be regarded as merely a mixture of carbon and iron with other *alloys*. He (the speaker) believed that carbon played a minor part in the deoxidation of steel. He had made experiments with the crucible process, with a view to endeavour to ascertain how steel was deoxidised. That process could afford a hint. Silica was a powerful oxidising agent of manganese, and in a less degree of iron at steel-melting temperatures. He attributed the fall of manganese during casting to the oxidation of the steel by the surplus silica of the ladle lining. In the reactions of the acid process, iron, as the temperature increased, tended to reduce silica, and the tendency of the bath was to reduce FeO. When steel was actually deoxidised, he believed it was by means of indirectly formed silicides of manganese, which made particularly good deoxidising agents when added as silicides. In the crucible process carbon was lost in the main during melting down. At first the silicon rose, then it fell when dead-melting was reached. When the melter tried to drive dead-melting in the crucible too far there was a sudden gain of slag, the neutralised silicates forming fluxes, which rose and formed a bulky slag in the crucible, exposing free silica, which re-oxidised the steel. It was only when the various reagents were mutually dissolved in the steel that they had a chance of thorough reaction. It might happen that the temperature was too low for carbon reactions, and in the case of simple ferrous-silicide reaction it might be too high. In the case of silicides of manganese such a temperature was not reached; there was practically always a silicide of manganese-ferrous oxide reaction, and for that reason he thought there was a tendency for acid steels to be better than basic. It was well known that manganese could be got into basic steel by adding peroxide of manganese. There was not an open-hearth gas furnace in the world in which a metal exactly like iron, except in being a noble metal, could be retained molten under a layer of ordinary slag; the heating surface in relation to the radiating surface was too small. The temperature limits of the refractories did not allow of means for overcoming the radiation losses. The slags were of a combustible nature, yet the term "equilibrium" was used; that equilibrium was very illusory. It meant that the reducing agents, including iron, were reducing peroxides down to protoxides as fast as they were formed. Owing to these various influences, drastic modifications of the process were required to render it possible to produce really, instead of very nearly, deoxidised steel. He further stated that when heating large forgings, blisters formed in the scale always occurred at the critical point, regardless of the temperature; the blistering, according to the critical point of the various alloy steels, varied over 150 deg. In concluding his remarks he expressed the hope that the more important elements would be taken into consideration, and that steel would not merely be regarded as a carbide of iron. In the acid process the elements present in bulk were silicon, iron and oxygen; this system, silicon, iron and oxygen, should be studied first, proceeding then element by element.

Mr. Morgans thanked the meeting for the remarks which had been passed, and added that he would reply to them in writing. Mr. Rogers said he would also reply in writing, and as for bibliographical data, to give these would take probably two volumes of the Institute's journal and would take up too much time.

On the motion of the chairman the authors were cordially thanked for their contributions.

A Note on the Microstructure of Commercially Pure Iron between Ar_3 and Ar_2.

The last paper taken at Friday's meeting was the one having the above title, by Messrs. W. J. Brooke and F. H. Hunting. It was read in abstract by the secretary. We propose to reproduce it in full in a future issue.

The discussion was opened by Professor Arnold, who said that he found the paper of very great interest, inasmuch as it involved the fundamental principles on which the theories concerning iron and steel were based. He (the speaker) mentioned the results of American tests made with a 2¼-in. square ingot of pure commercial iron cast from a crucible and rolled down to ⅝-in. bars. The normal bar was cut up into lengths and made into screw test specimens; these were heated in an atmosphere of nitrogen and quenched. The results of mechanical tests were very different from those given by the authors The maximum stress varied from 20 tons to 31 tons, and the quenching temperatures varied up to 925 deg. He drew a curve on the blackboard which from atmospheric to about 500 deg. exhibited a practically straight line, then the curve went up to 925 deg., when the maximum stress was 31 tons. This showed the effect of quenching. The critical points did not affect the results; the reduction of area remained constant at 75 per cent. The authors had said that between the Ar_3 and Ar_2 points, and with an iron of the relative purity of the one dealt with, a eutectoid, probably composed of iron carbide, phosphide and sulphide, was thrown out from the ferrite grains to the boundaries; he thought this might apply to the sulphide of iron, but the phosphide of iron remained in solution and the carbide of iron was not thrown out. In the authors' Fig. 8 the patch was one of pearlite, or, rather, hardenite, and the edge was cementite, probably mixed with sulphide. He gave on the blackboard a curve showing the point Ar_3 at 900 deg., the first peak Ar_2 at 765 deg. and the second

peak at 745 deg., and it puzzled him that the authors did not find the latter.

Dr. Rosenhain found that the attempt made by the authors was a very satisfactory one, in motive rather than in its results, to solve the problem in regard to the material dealt with. He had also noticed the red-shortness referred to by the authors. The only way to explain red-shortness was to study the tensile properties at high temperatures and the microstructures also at high temperatures. There was no difficulty in finding the arrest points in this material, and the authors had not found them probably because their apparatus were not adapted to the purpose.

Dr. C. H. Desch said the brittleness within the range of temperatures quoted was very remarkable. In regard to the microstructures, he had carried out experiments which confirmed what the authors had found. If quenched within limits there were the eutectoid structures referred to. His impression was that the nitrogen was concerned.

Dr. W. H. Hatfield stated that he had made a large number of experiments on pure Swedish iron, heat treating and taking microsections of the specimens; he had great pleasure in confirming the authors' eutectic structure. He was at a loss to understand it, but did not think it was due to nitrogen.

Mr. E. H. Saniter would like the authors to add to their table of tests the reduction of area. He questioned whether they meant elastic limit or yield-point, but was inclined to think that their figures applied to the yield-point. He hardly thought nitrogen was the cause of the pearlite structure; as there was in the iron 0.03 of oxygen there was ferrous oxide, and this had much to do with the matter.

Mr. J. P. Bedson said he had worked with the material experimented with by the authors, and had found it a remarkable one in electrical apparatus. The stress figures of Armco were about the same as those of Swedish iron, and in regard to ductility it was more like copper than anything else. It did not harden in the process of drawing. In the matter of red-shortness it had to be rolled at a low temperature, and in a continuous mill it was possible to start under a temperature of 800 deg. and to continue the operation until a rod was finished.

The chairman thanked the authors for their contribution, and announced that their replies would be given in writing.

The two other papers on the list, *i.e.*, "The Influence of Heat Treatment on the Electrical and Thermal Resistivity and Thermo-Electric-Potential of Some Steels," by Messrs. E. D. Campbell and W. C. Dowd, and "The Eggertz Test for Combined Carbon in Steel," by Mr. J. H. Whiteley, were taken as read. The usual votes of thanks to the Institution of Civil Engineers for the accommodation which they had kindly afforded for the meeting, and to the chairman, concluded the proceedings.

INVESTIGATION UPON A CAST OF ACID OPEN-HEARTH STEEL.*

By T. D. MORGANS (Blaenavon, Mon.) and F. ROGERS, D.Eng., B.A., M.Sc. (Sheffield).

THE work described in the present paper was undertaken at the special request of Colonel Stansfeld, C.B., Deputy Director-General of Munitions Inspection, with a view to determining the general quality and uniformity of the acid open-hearth steel made at the Blaenavon Company's works for the manufacture of high explosive shell.

The plan of the investigation consisted in making the following analyses and tests from pit samples and from the top, middle, and bottom billet from one of the 40-ton acid open-hearth furnaces :—

1. Analyses of pit samples taken immediately before casting each ingot (Table I).
2. Analyses of the top, middle and bottom billet from each ingot (Tables II, III and IV).
3. Tensile test from the top, middle and bottom billet from each ingot (Table V, page 357).
4. Brinell test from the same (Table V).
5. Microscopic examination of the same.

The results of the tests are plotted in the diagram on page 356, and a representative selection of photomicrographs are reproduced in Figs. 1 to 20 (Plates XXXIV and XXXV).

Experimental Cast. (Cast No. 174).—The following are the general particulars of the cast investigated :—

Composition of the Charge.	Tons.	Cwt.	Qr.
Pig-iron	19	1	0
Heavy scrap	21	8	0
Shell steel turnings	3	0	0
Ferro-manganese	0	11	3
Ferro-silicon (50 per cent. silicon)	0	2	1
Iron ore	2	0	0
Limestone, about	0	14	0
Total	46	17	0

	Hours.	Minutes.
Commenced charging ...	12	50 a.m.
Finished charging	6	0 ,,
Charge melted	10	15 ,,
Charge boiling	11	0 ,,
Tapped	2	10 p.m.

Total time taken for charge, 13 hours 20 minutes. The ferro-manganese and ferro-silicon were put into the bath; none into the ladle.

TABLE I.—*Analyses of Pit Samples.*

Cast.	Ingot.	Carbon.	Phosphorus.	Sulphur.	Manganese.	Silicon.
174	1	0.506	0.043	0.062	0.840	0.172
174	2	0.512	0.044	0.063	0.875	0.178
174	3	0.497	0.043	0.060	0.820	0.175
174	4	0.508	0.043	0.063	0.785	0.169
174	5	0.491	0.042	0.057	0.830	0.168
174	6	0.521	0.043	0.060	0.845	0.178
174	7	0.513	0.039	0.059	0.785	0.180
174	8	0.500	0.042	0.059	0.790	0.182
174	9	0.526	0.040	0.061	0.840	0.178
174	10	0.517	0.041	0.061	0.840	0.179
174	11	0.509	0.042	0.061	0.790	0.174
174	12	0.496	0.040	0.056	0.795	0.180
174	13	0.499	0.040	0.057	0.765	0.174
174	14	0.526	0.042	0.060	0.810	0.174
174	15	0.513	0.042	0.057	0.810	0.174
174	16	0.541	0.042	0.062	0.840	0.174
174	17	0.526	0.041	0.060	0.805	0.168
174	18	0.519	0.044	0.060	0.795	0.169
174	19	0.551	0.044	0.055	0.795	0.176
174	20	0.507	0.043	0.055	0.805	0.176
174	21	0.512	0.042	0.054	0.765	0.169
174	22	0.519	0.044	0.054	0.785	0.174
	Maximum ..	0.551	0.044	0.063	0.875	0.182
	Minimum ..	0.491	0.039	0.054	0.765	0.168
	Range ..	0.060	0.005	0.009	0.110	0.014
	Mean ..	0.514	0.042	0.059	0.810	0.175

TABLE II.—*Analyses of 4-in. Billets.* (*Finished Top Bars.*)

Cast.	Ingot.	Billet.	Carbon.	Phosphorus.	Sulphur.	Manganese.	Silicon.
174	1	7	0.546	0.046	0.059	0.870	0.175
174	2	7	0.545	0.045	0.058	0.875	0.179
174	4	7	0.550	0.045	0.058	0.865	0.180
174	5	7	0.547	0.044	0.059	0.865	0.182
174	6	7	0.543	0.044	0.057	0.855	0.182
174	7	7	0.545	0.045	0.057	0.855	0.176
174	8	7	0.549	0.044	0.059	0.855	0.176
174	9	7	0.550	0.048	0.058	0.850	0.176
174	10	7	0.563	0.044	0.058	0.845	0.179
174	11	7	0.551	0.044	0.059	0.850	0.178
174	12	7	0.545	0.044	0.058	0.840	0.177
174	13	7	0.539	0.045	0.058	0.840	0.177
174	14	7	0.536	0.045	0.057	0.840	0.175
174	15	7	0.530	0.044	0.058	0.830	0.177
174	16	7	0.530	0.044	0.059	0.830	0.176
174	17	7	0.525	0.045	0.058	0.835	0.176
174	18	7	0.531	0.044	0.059	0.815	0.178
174	19	7	0.536	0.043	0.056	0.800	0.177
174	20	7	0.538	0.046	0.055	0.810	0.177
174	21	7	0.539	0.045	0.059	0.785	0.177
	Maximum ..		0.563	0.048	0.059	0.875	0.182
	Minimum ..		0.525	0.043	0.055	0.785	0.175
	Range ..		0.038	0.005	0.004	0.090	0.007
	Mean ..		0.542	0.045	0.058	0.840	0.177

TABLE III.—*Analyses of 4-in. Billets.* (*Finished Middle Bars.*)

Cast.	Ingot.	Bar.	Carbon.	Phosphorus.	Sulphur.	Manganese.	Silicon.
174	1	4	0.519	0.039	0.058	0.845	0.171
174	2	4	0.540	0.041	0.058	0.845	0.171
174	4	4	0.521	0.039	0.058	0.845	0.172
174	5	4	0.528	0.042	0.056	0.845	0.174
174	6	4	0.527	0.040	0.052	0.840	0.174
174	7	4	0.520	0.044	0.055	0.845	0.173
174	8	4	0.529	0.044	0.055	0.845	0.173
174	9	4	0.529	0.042	0.056	0.845	0.173
174	10	4	0.536	0.041	0.057	0.845	0.171
174	11	4	0.521	0.045	0.057	0.840	0.173
174	12	4	0.529	0.041	0.055	0.845	0.175
174	13	4	0.512	0.044	0.052	0.845	0.176
174	14	4	0.509	0.045	0.056	0.820	0.175
174	15	4	0.521	0.045	0.055	0.825	0.174
174	16	4	0.512	0.043	0.054	0.815	0.174
174	17	4	0.531	0.043	0.053	0.835	0.174
174	18	4	0.526	0.044	0.054	0.820	0.173
174	19	4	0.541	0.045	0.054	0.800	0.172
174	20	4	0.516	0.044	0.054	0.810	0.174
174	21	4	0.532	0.044	0.054	0.775	0.173
	Maximum ..		0.541	0.045	0.058	0.845	0.175
	Minimum ..		0.509	0.039	0.052	0.775	0.171
	Range ..		0.032	0.006	0.006	0.070	0.004
	Mean ..		0.524	0.043	0.055	0.831	0.173

TABLE IV.—*Analyses of 4-in. Billets.* (*Finished Bottom Bars.*)

Cast.	Ingot.	Bar.	Carbon.	Phosphorus.	Sulphur.	Manganese.	Silicon.
174	1	1	0.515	0.037	0.052	0.855	0.173
174	2	1	0.520	0.039	0.051	0.855	0.172
174	5	1	0.518	0.037	0.050	0.840	0.170
174	6	1	0.523	0.038	0.050	0.840	0.169
174	7	1	0.525	0.038	0.050	0.835	0.171
174	8	1	0.526	0.038	0.048	0.840	0.170
174	9	1	0.531	0.038	0.050	0.850	0.172
174	10	1	0.530	0.038	0.049	0.845	0.170
174	11	1	0.536	0.037	0.054	0.840	0.169
174	12	1	0.520	0.038	0.053	0.865	0.170
174	13	1	0.518	0.042	0.047	0.835	0.170
174	14	1	0.519	0.038	0.053	0.830	0.162
174	15	1	0.509	0.042	0.052	0.825	0.163
174	16	1	0.510	0.041	0.054	0.810	0.160
174	17	1	0.507	0.039	0.052	0.810	0.165
174	18	1	0.511	0.038	0.053	0.805	0.164
174	19	1	0.526	0.040	0.053	0.805	0.162
174	20	1	0.509	0.039	0.051	0.795	0.162
174	21	1	0.517	0.041	0.052	0.780	0.160
	Maximum ..		0.536	0.042	0.054	0.865	0.173
	Minimum ..		0.507	0.037	0.047	0.780	0.160
	Range ..		0.029	0.005	0.007	0.085	0.013
	Mean ..		0.519	0.039	0.051	0.829	0.167

Analysis of slag taken at the end of the process after the addition of the alloys :—

	Per cent.
Silica (SiO_2)	55.67
Alumina (Al_2O_3)	4.11
Oxide of iron (FeO)	17.63
Lime (CaO)	10.04
Manganese oxide (MnO)	13.02
Sulphur and phosphorus (S and P) ...	traces
Magnesia (MgO)	0.82

Colour of slag, bottle-green.

Size of mould ... 18¼ inches by 16¼ inches (top).
,, ,, ... 16¼ ,, 14 ,, (bottom).

Top of mould brick lined to the depth of 11 in.

Total length of ingot, 5 ft. 6 in. (including head). Ingots teemed in pairs. Approximate weight of ingot, 40 cwt. The time taken to teem the whole cast was 25 minutes.

Slag was taken for analysis after the addition of the alloy and after teeming metal into ladle. The bath was caught coming down (no pigging back).

Ore not used after carbon in bath reached 0.70 per cent.

Analyses of Pit Samples (*Table I*).—These figures will be readily appreciated upon reference to the mean, maximum, minimum, and range of variation shown at the foot of the table. The range of variation of carbon is 0.06 per cent.; phosphorus, 0.005 per cent.; sulphur, 0.009 per cent.; manganese, 0.110 per cent.; silicon, 0.014 per cent. Practically the irregularities in carbon, phosphorus and silicon are negligible. The variations of sulphur and manganese are more noticeable, but on reference to the table and the diagram, page 356, it will be seen that there has been a fairly general fall of sulphur and manganese during the teeming of the ingots, a period of about twenty minutes. The fall of sulphur (0.009 per cent.) is much lower, however, in relation to the fall of manganese (0.11 per cent.) than would be the case if the removal of manganese sulphide were the sole action.

These results therefore give very strong evidence that the fall in manganese is mainly due to the continuance of its deoxidising action.

The drop in sulphur and manganese in the ladle has occasionally been found by other observers.

Analyses of the Top, Middle and Bottom Billet of each Ingot (*Tables II, III and IV*).—The primary feature of the analyses is their regularity. The variation of the sulphur no longer follows a definite fall. This is possibly because the ingot is drawn from a considerable part of the ladle, whilst naturally the pit sample can only represent a small fraction near to the nozzle at the moment of taking it. The agitation in the ladle during teeming the ingot would possibly be sufficient to mask the tendency evidenced only in the pit samples to removal of MnS.

Manganese in each case appears definitely to fall. The removal of manganese in the ladle may, the authors consider, be taken as distinctly established throughout the present experiments, and this is mainly due to the continuance of its deoxidising action.

In the bottom bars (Table IV) silicon also appears to have fallen, but we consider that an explanation founded upon this result might be rather hazardous.

The mean results are assembled in the following table :—

—	Carbon.	Phosphorus.	Sulphur.	Manganese.	Silicon.
Mean, top bars ..	0.542	0.045	0.058	0.840	0.177
,, middle bars ..	0.524	0.043	0.055	0.831	0.173
,, bottom bars ..	0.519	0.039	0.051	0.829	0.167
Range of means ..	0.023	0.006	0.007	0.011	0.010
Mean of means ..	0.528	0.042	0.055	0.833	0.172
Pit sample means ..	0.514	0.042	0.057	0.810	0.175

This shows distinctly the usual slightly higher percentages of elements found in the upper ends of ingots.

The comparison between the means of pit samples and of bar samples shows fair consistency in view of the much superior nature of the general "sample"

* Paper read before the Iron and Steel Institute, September 21, 1917.

constituted by the means from the bars, as compared with the mean pit sample.

It should be noted, as a rough generalisation upon the whole of the analyses, that the range of variation in each element is of the order of one-tenth of the amount of the element present (*i.e.*, 5 per cent. each way from the mean value), with the exception of silicon in the top and middle bars, which is less than this proportion, and carbon in all the bars, which varies only about 3 per cent. up and down from the mean. The authors would point out that this degree of variation compares favourably with tests upon single casts which within their experience have been obtained in works practice, and is closer than is usually obtained upon successive similar casts.

Tensile Tests and Hardness Tests (*Table V*, page 357).—The tensile and hardness tests, in view of their practically featureless uniformity, call for very little comment. It is seen that the tests are well up to standards for this class of steel without futher heat treatment after rolling to 4-in. square billets.

Tests upon the Forged Shell.—It has been possible to add some results of tests taken from the walls of the shell which were forged from this cast. (See Table VI.)

It is seen that these results are well in accordance with the usual specifications for steel of this class; and they show the maintenance of that regularity in quality which was indicated in the more exhaustive tests upon the semi-finished steel already discussed.

Fig. 22.

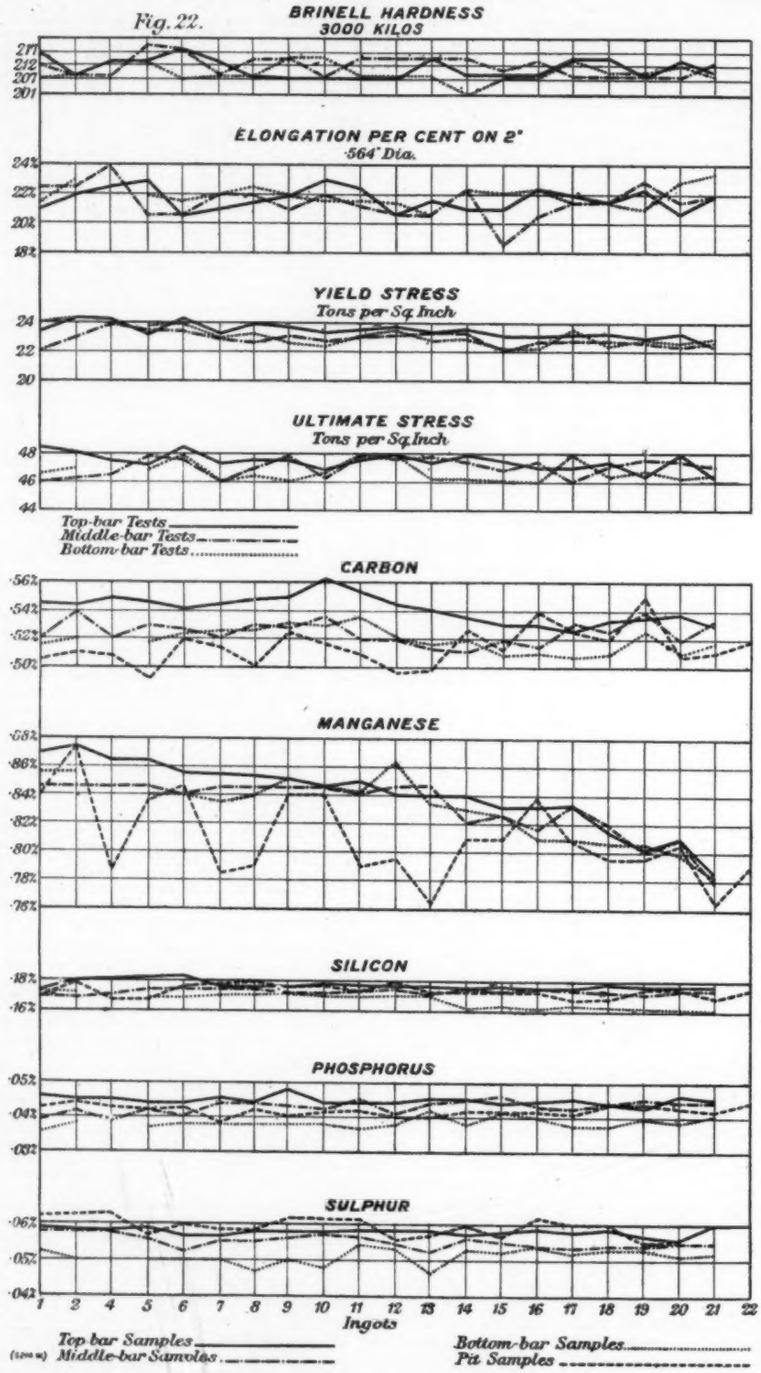


Fig. 23.

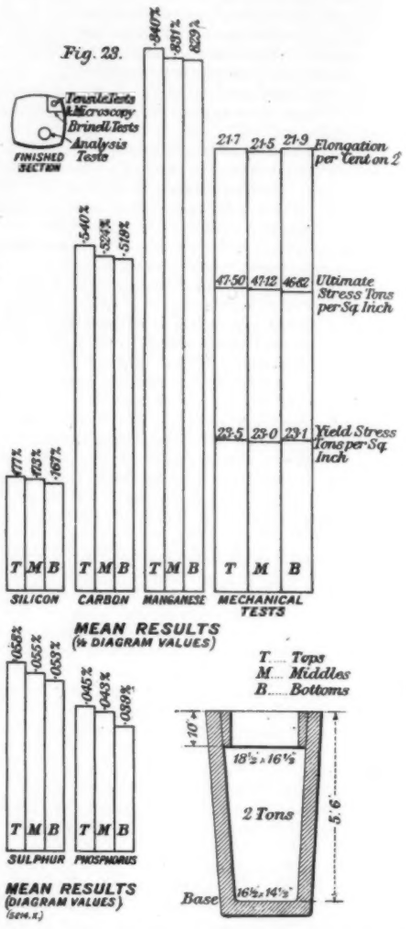


TABLE VI.—*Tensile Tests on 4.5-in. Shell Forgings.*

Elastic Limit. Tons per sq. in.	Maximum Stress. Tons per sq. in.	Elongation per cent. on 2 in.
Over 19	48.1	21.6
„ 19	47.6	21.6

Section of Ingot.—Fig. 21 on Plate XXXV, shows a photograph of a section of an ingot from another cast, A20, the particulars of whose manufacture are practically identical with those given on page 355 for the experimental cast, all the ingots of which were rolled into billets. This ingot was teemed in 2½ minutes. Its weight was 1 ton 18 cwt. 0 qr. 18 lb.; and the weight of top discard was 4 cwt. 2 qr. 20 lb., which is 12.26 per cent. of the total weight of the ingot. The following is the chemical analysis of this ingot:—

Carbon per cent.	Silicon per cent.	Sulphur per cent.	Phosphorus per cent.	Manganese per cent.
0.44	0.164	0.050	0.045	0.820

The tensile test from the same cast rolled to 4-in. billets was:—

Elastic Limit. Tons per sq. in.	Maximum Stress. Tons per sq. in.	Elongation per cent. on 2 in.
21.9	43.4	22

The photograph (Fig. 21) will show that the pipe is very satisfactorily located in the head, and its form indicates no tendency to secondary pipe.

Microstructure.—The photomicrographs, Figs. 1 to 17 (Plates XXXIV and XXXV), are taken under comparative conditions from 17 of the billets at random. The position of the field photographed is in every case approximately upon the continuation of the axis of the tensile test-piece, and near one corner of the section of the billet, about ¼ in. from each of the two neighbouring sides. The magnification is 50 diameters.

The three photomicrographs, Figs. 18 to 20 (Plate XXXV), at a higher magnification (500 diameters) show in greater detail the nature of the structure in the same positions.

The structure consists of a ferrite network, which is partially discontinuous in places, whose meshes are filled with generally lamellar pearlite. Towards the edges of the billet the network size is smaller, and towards the centre larger than at the field adopted as standard for the photomicrographs. In many places there are isolated large meshes (or local discontinuities of the network, according to the point of view). Throughout the general microscopic examination of all the pieces no features were encountered which could be classed as defects in a steel of this class. The variations of structure which were encountered were such as ordinarily occur in good steel of this class. Such variations, including local differences of network size, were not in any instance of a nature which would prove detrimental to the steel for the purposes for which it was intended.

The Blaenavon Company desire to take this opportunity of expressing their thanks to Colonel Stansfeld, C.B., for his keen interest in the investigation throughout and for sanction to publish the results; and also to Mr. Jackson, late of the Midland Railway Engineering Department, Inspector of the Munitions Area, who has actively participated in the progress of the work and kindly prepared the diagram.

TABLE V.—*Tensile and Brinell Hardness Tests on 4-in. Billets. Billet Position (Bottom).*

Ingot No.	Yield Stress.	Maximum Stress. Tons per sq. in.	Elongation per cent.	Fracture.	Brinell Test on 3,000 kilos Hardness Number.
			Per cent.		
1	24.0	46.8	21.5	F	207
2	24.4	47.2	23.0	F	207
5	23.8	46.8	22.0	F	212
6	24.0	48.08	21.5	90 F	207
7	22.8	46.16	22.0	F	207
8	23.2	46.6	22.5	F	207
9	22.6	46.08	22.0	F	212
10	22.6	46.6	21.5	90 F	212
11	23.2	47.8	21.5	90 F	207
12	23.6	47.8	21.5	90 F	207
13	22.8	46.4	20.5	80 F	207
14	23.2	46.32	22.5	F	201
15	22.4	46.2	22.0	90 F	207
16	22.4	46.08	22.5	F	207
17	23.8	48.08	21.5	90 F	212
18	22.6	46.4	21.5	90 F	207
19	22.8	47.2	21.0	90 F	207
20	22.8	46.4	23.0	F	212
21	22.8	46.6	23.5	F	207
Average..	23.15	46.82	21.94	—	208
Maximum	24.4	48.08	23.5	—	212
Minimum	22.4	46.2	20.5	—	201
Range ..	2.0	1.88	3.0	—	11
Billet Position 4 (Middle).					
1	22.0	46.0	22.5	90 F	212
2	23.0	46.2	22.5	F	207
4	24.2	46.52	24.0	F	207
5	23.6	47.88	20.5	90 F	217
6	23.6	47.6	20.5	60 F	217
7	22.8	46.2	22.0	90 F	207
8	22.8	47.0	22.0	90 F	212
9	23.2	47.88	21.0	60 F	212
10	22.8	46.28	22.0	F	207
11	23.2	47.8	21.0	50 F	212
12	23.4	47.6	20.5	50 F	212
13	23.4	47.84	20.5	50 F	212
14	23.4	47.4	22.5	90 F	212
15	22.4	46.8	18.5	50 F	207
16	22.8	47.6	20.5	60 F	212
17	22.8	46.2	21.5	F	207
18	22.8	47.2	21.5	60 F	207
19	22.8	47.72	23.0	F	207
20	22.6	47.6	21.5	70 F	207
21	22.6	47.08	22.0	80 F	212
Average..	23.01	47.12	21.5	—	210
Maximum	24.2	47.88	24.0	—	217
Minimum	22.0	46.0	18.5	—	207
Range ..	2.2	1.88	5.5	—	10
Billet Position 7 (Top).					
1	23.6	48.28	21.0	60 F	217
2	24.4	48.0	22.0	F	207
4	24.4	47.32	22.5	F	212
5	23.4	47.2	23.0	F	212
6	24.6	48.6	20.5	60 F	217
7	23.2	47.2	21.0	90 F	212
8	24.0	47.52	21.5	90 F	207
9	23.8	47.72	22.0	F	207
10	23.2	46.72	23.0	F	207
11	23.6	47.68	22.5	90 F	207
12	23.8	47.84	20.5	60 F	207
13	23.4	47.52	21.5	60 F	212
14	23.6	47.88	21.0	90 F	207
15	23.2	47.72	21.0	50 F	207
16	23.0	47.12	22.5	F	207
17	23.2	47.0	22.0	90 F	212
18	23.2	47.52	21.5	80 F	212
19	22.8	46.6	22.5	F	207
20	23.0	48.08	20.5	40 F	212
21	22.4	46.48	22.0	90 F	207
Average..	23.49	47.5	21.7	—	210
Maximum	24.6	48.6	23.0	—	217
Minimum	22.4	46.48	20.5	—	207
Range ..	2.2	2.12	2.5	—	10

	Tons per sq. in.
Average yield stress of whole cast	23.21
,, maximum ,, ,, ...	47.15
	Per cent.
,, elongation ,, ,, ...	21.71
,, Brinell hardness number	209.0

Ingots 3 and 4.—Electric power failed at roughing of ingot 3, and bottom billet of ingot 4 too cold to finish. Hence the omission of these tensile and hardness tests.

To the gentlemen named the authors also beg to express their thanks, and also to the Blaenavon Company for their kind permission to publish this paper.

TIN AND WOLFRAM IN BRITISH MALAYA.—Though it is the most backward of the native States in the Malay Peninsula, the State of Trengganu has shared in the general prosperity of British Malaya during the past year. Mr. J. L. Humphreys, the British Agent at Kuala Trengganu, in his annual report states that in spite of the land office being, as yet, inadequately equipped for dealing with mining matters, there was considerable prospecting activity during the year. It is hoped that a suitable mining enactment will be passed shortly and the department placed in a better position for dealing with applications. Very large areas of the State, which is on the eastern side of the Peninsula, remain unprospected, and others are locked up in undeveloped concessions. There is every reason to anticipate a good mining future for the State when an improvement in the administration has provided greater security and improved means of communication.

THE EFFECT OF GREAT HYDROSTATIC PRESSURE ON THE PHYSICAL PROPERTIES OF METALS.*

By ZAY JEFFRIES, B.Sc., Met.E., Assistant Professor of Metallurgy, Case School of Applied Science, Cleveland, Ohio, U.S.A.

THE effect of cold hammering of metals without deformation is discussed in *Comptes Rendus*, 1912, vol. 155, page 1,502, by M. Hanriot. He comes to the conclusion that metals subjected to enormous hydrostatic pressures, say, about 10,000 kg. per square centimetre, even though producing no change in shape of the pieces of metal, will show an increase in hardness.

Dr. P. W. Bridgman, Cambridge, Mass., very kindly consented to subject some pieces of metal to great hydrostatic pressure. I have determined certain physical properties of these pieces of metal, and find no substantial difference in physical properties before and after subjection to these great hydrostatic pressures. I have also examined the pieces of metal microscopically, and there seems to be no change in structure due to the hydrostatic pressure.

A review of Hanriot's experiments and a description of the writer's experiments will be given in this paper, together with a discussion of the results.

Hanriot first performed experiments in a cylindrical mortar 50 mm. diameter, which was fitted with two closely fitting steel cylinders acting as pistons, and between these two pistons he placed a silver cylinder of the same diameter as the pistons, and 15 mm. high. One piston was given 10 blows with a heavy bar. The apparatus was then taken to pieces, and it was observed that the silver had been deformed somewhat. The hardness before hammering was 23.5, and after hammering it was 39.5. This experiment confirms what is already very well known, namely, that when a malleable metal is deformed by means of hammer blows or otherwise, at a sufficiently low temperature, it increases in hardness.

Hanriot's next experiment was to subject small pieces of metal to a hydrostatic pressure of about 10,000 kg. per square centimetre. Cubes of silver, copper and aluminium were subjected to hydrostatic pressure, and the Brinell hardness compared before and after the pressure treatment. The hardness tests are as follow :—

Brinell Hardness.

——	Before Compression.	After Compression.	Hammering Effect.
Silver	19.4	36.0	1.80
Copper	27.0	46.1	1.70
Aluminium ..	14.6	19.0	1.30

Hanriot states that in no case were the cubes appreciably deformed, and concludes that the pressure was sufficient for hard hammering the metals without deformation.

We have performed the following experiments with pure aluminium and with an alloy consisting of 88 per cent. aluminium and 12 per cent. copper; cylinders of these metals were prepared $\frac{7}{16}$ in. diameter by $\frac{1}{2}$ in. long. The cylinders were machined and the dimensions measured with a micrometer. Hardness tests and tensile tests were made upon the original samples, with the following results :—

	Tensile Strength.	Scleroscope Hardness.
	lb. per sq.in.	
Aluminium	14,890	6.5
Aluminium-copper alloy ...	31,950	24.0

Some of the cylinders of each kind of metal were subjected to the following treatment, which will be designated as treatment A :—Exposed to pressure at 25 deg. C.; transmitting liquid, petroleum ether mixed with kerosene; maximum pressure, 12,400 kg. per square centimetre; pressure maintained near maximum for 20 minutes; total time occupied in raising pressure to maximum and releasing, about 2½ hours. After subjecting these cylinders to the treatment above outlined the dimensions were measured with a micrometer and were found to be the same as before the pressure treatment.

Tensile tests and hardness tests were made, with the following results :—

Treatment A.

	Tensile Strength.	Scleroscope Hardness.
	lb. per sq. in.	
Aluminium	14,300	6.5
Aluminium-copper alloy ...	27,300*	24.0

* Threads stripped, piece not broken.

Other similar cylinders were subjected to the following treatment, which will be designated as treatment B :—Exposed to pressure at 40 deg. C.; transmitting medium, kerosene; maximum pressure, 12,400 kg. per square centimetre; pressure was in the neighbourhood of the maximum for 20 minutes; total time occupied in raising pressure to maximum and releasing, about 2½ hours. The metal cylinders showed no change in shape after being subjected to this pressure treatment. The physical properties after the metals had been subjected to the above treatment were found to be as tabulated :—

* Paper read before the Institute of Metals on September 19.

Treatment B.

	Tensile Strength.	Scleroscope Hardness.
	lb. per sq. in.	
Aluminium	15,250	6.5
Aluminium-copper alloy ...	33,200	24.0

It can be concluded from the results that hydrostatic pressure up to 12,400 kg. per square centimetre, applied at temperatures from 25 deg. to 40 deg. C., has practically no effect on the hardness and tensile strength of aluminium, or an aluminium-copper alloy containing 88 per cent. aluminium and 12 per cent. copper. Furthermore, the microstructure of the metals seemed to be the same before and after subjection to hydrostatic pressure.

These results contradict Hanriot's, inasmuch as he obtained an increase in hardness of 30 per cent. on aluminium by the application of hydrostatic pressure of about 10,000 kg. per square centimetre. Dr. Bridgman calls attention to the fact that Hanriot used vaseline to transmit the pressure, and that vaseline freezes hard under pressure, so that at the higher pressures the stress that Hanriot applied could not have been hydrostatic. Dr. Bridgman's explanation of Hanriot's results seems very plausible.

To determine the effect of almost immeasurable degrees of deformation on these small cylinders of aluminium and aluminium-copper alloy, letters were stamped on one end by means of hammering steel letter stencils. The external dimensions of the cylinders were not appreciably changed, but the impressions of the letters were easily visible. Hardness tests on the aluminium cylinders showed an increase on the stencilled end of about 50 per cent., and with the aluminium-copper alloy the increase in hardness on the stencilled end was about 30 per cent. It is thus evident that a very slight degree of deformation, produced by mechanically applied stress, may change the hardness locally in a degree which is not at all commensurate with the degree of change of shape of the piece taken as a whole. It is true that the metal was deformed severely at the stencil marks, but the measurement of the external dimensions of the pieces with a micrometer showed practically no change.

If Dr. Bridgman's line of reasoning is correct regarding Hanriot's results, the above experiment may illustrate why Hanriot could actually produce sufficient deformation in the pieces of metal to change the hardness, but probably not sufficient to measure with the instruments he used.

On the other hand, another possible explanation may be that the metals undergo allotropic changes at high pressures, and the physical properties of the resultant allotropic modifications may be different from the physical properties of the modifications which exist before the application of pressure. It is reasonable to suppose, however, if this be the true explanation of Hanriot's observed increase in hardness, that some of the new allotropic modifications would be softer than the modifications existing before the application of pressure. Inasmuch as all of Hanriot's results point to an increase in hardness, the theory of a slight permanent deformation as the immediate cause of increased hardness is much more plausible. Besides, if aluminium had been changed to a harder allotropic modification by Hanriot's treatment, it should have been so changed in the treatments, using even greater pressure, outlined above.

Both the aluminium and aluminium-copper alloy had fine-grained structures. Since the grains are haphazardly oriented, there would be a tendency for these metals to act under great pressure like amorphous or isotropic substances; the resistance to deformation would be the same in all directions, and hence no permanent deformation would result from great hydrostatic pressure. On the other hand, a single crystal or a piece of metal composed of a few large grains might actually suffer permanent deformation when subjected to great hydrostatic pressure, due to the different degrees of resistance to deformation in certain directions. These directions would be determined by the orientation of the crystal or crystals. In case of such permanent deformation the hardness would increase.

It is highly probable that all of Hanriot's results are as far out as his results with aluminium, and that the hardness of metals cannot be increased without actual permanent deformations, unless such increase in hardness is due to an allotropic change. If an allotropic change take place, a change in volume might reasonably be expected, and hence an apparent permanent deformation might be noted. In such case the hardness might be as apt to decrease as increase.

In the Transactions of the Faraday Society, May, 1915, page 258, McCance quotes Hanriot's conclusions as being authentic, and considers this information as a possible reason for the hardening of steel on quenching, due to the development of great internal pressure. It will be evident from the foregoing that McCance's line of reasoning is subject to question, but that the ultimate effect which he desires to have produced may be accounted for in steel because of the actual change of volume in the steel during the transformations accompanying the hardening phenomena.

STANDARDISATION OF AERO-ENGINE RADIATORS.—In the recently published annual report of the Advisory Committee for Aeronautics it was stated that the investigations on the subject of aeroplane radiators had been brought to a conclusion, and recommendations made for standardisation. Effect has now been given to these conclusions by the Air Board, and a confidential circular letter has been issued to aeroplane contractors and radiator makers, instructing them as to the material which is to be used for this purpose in future designs. Inquiries on the subject may be addressed to the Department of Aeronautical Supplies, Room 609, Air Board Office, Strand, W.C. 2.

THE ACID OPEN-HEARTH PROCESS.*

By F. Rogers, D.Eng., B.A., M.Sc. (Sheffield).

Whilst numerous writers have dealt with the general metallurgy of the acid open-hearth amongst the other steel-making processes, they have, on the whole, left room for a reasonable claim that persistent mystery and some ignorance continually enshroud steel-making, especially by the acid open-hearth and crucible processes.

Many of the views and suggestions in the present paper will have a direct or indirect bearing upon steel-making by all the six usual processes, but attention has been centred upon the acid open-hearth process, partly for the reason mentioned, and also because for a considerable period of years acid open-hearth steel has remained in this country a sort of standard of reference for quality amongst structural steels. Further, the metallurgy of this process offers in many respects a convenient starting-point for the study of all the steel-melting processes.

In all the oxidising processes it is essential at the end to deoxidise the metal by some means. The prime effect of neglect to do so is blowholes in the ingot, a defect which in the majority of cases is inadmissible. There is also considerable evidence which suggests, but as yet does not prove beyond doubt, that beside the gases (mainly oxygen in some form and hydrogen and nitrogen) which cause blowholes, further gas, including oxygen, remains in combination or solution in the steel, to its detriment.

Two principal methods are in use which contribute to secure the desired end. The first is the bringing of the bath to proper "condition" towards the end of the melting process; this factor assumes exceptional importance in the open-hearth acid process. The second is the use of deoxidisers.

The term "condition" is often abused in its application to steel-melting, being used in a vague and mysterious manner, frequently to cloak ignorance. It is true that it is not yet possible to keep the working under the continuous control of instantaneous precise measurement, but there is every reason why this fundamentally important "condition" should be as fully understood as possible.

What is meant by "the condition of the bath" is properly its temperature, the composition (particularly the carbon and oxygen contents) of the metal, and the composition (particularly the iron oxide content) of the slag.

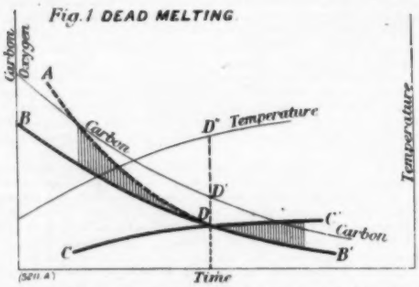
There are many considerations involved in judging the "condition" during working. After the primary aim, the adjustment of the carbon content, is well in hand, the deoxidation of the metal should occupy first place. The diminution of oxygen in the metal is indicated by the appearance of the sample and by the quieting down of the reaction, in conjunction with the carbon content of the metal, the composition of the original charge and slag, so far as known, and the temperature.

"Dead-melting" means the minimising of oxygen in the metal at this stage. The influence of temperature in dead-melting is usually misunderstood. The reaction between iron oxide and carbon in the bath proceeds further in the direction of minimising the total iron oxide present, as the temperature is raised. On the other hand, the rate of oxidation of the bath by the furnace atmosphere increases with the temperature. In practice, however, under ordinary conditions, the author has found that the balance is strongly in favour of the higher temperature. No satisfactory figure for the temperature can be given, since the means of measurement hitherto available are always open to an error of 20 deg. to 30 deg. C., and this amount is sufficient to make the difference between good dead-melting and bad.

Fig. 1, with its legend, illustrates this point. It has already been mentioned that it is important to minimise the small amount of oxygen which remains in the metal. The foregoing remarks, however, would apply equally well if we were merely contemplating the minimising of oxygen in the slag, but in some of the following remarks this would not apply, and it may therefore be taken that the author considers oxygen as being present in the bath (and in the solid steel) in small amounts as dissolved iron oxide.

The bearing of these views, however, is less clear unless it be realised that he considers that when dead-melting is achieved there is an appropriate equilibrium involving the retention of an amount of iron oxide in solution in the molten metal which is quite a definite amount in relation to the other factors involved (temperature, carbon principally, in presence of iron, silica principally). The equilibrium here referred to is not a stationary condition, but the reaction still continues in passing through this condition. The influence of lime (if present) in this equilibrium should here again be mentioned for the sake of completeness.*

The addition of lime causes in effect the displacement of some iron oxide (although the entire slag remains an approximately homogeneous solution) which reacts with carbon in the metal, thus lessening the total iron oxide in the system. The effect is slightly increased because the distribution of iron oxide between slag and metal will (upon well-understood physical and chemical grounds) be proportioned to the total iron oxide present—that is, the addition of lime does not merely lessen the iron oxide in the slag, but also lessens the iron oxide in the metal correspondingly. The diagram (Fig. 1) represents this:—



Curve "Carbon" shows the bath carbon content (C) in relation to the time (t).

Curve "Temperature" shows the corresponding temperatures.

Curve BB' shows the oxygen (O) taking part in the reaction FeO + C = Fe + CO; the equation of the curve is $O = -\frac{16}{12}\frac{dC}{dt}$.

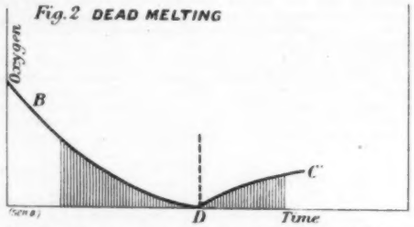
Curve CC' shows the oxygen entering the slag from the atmosphere. CC' and BB' intersect at D.

Curve AD shows the total oxygen present in the bath previous to D. The curve AD frequently meets BB' elsewhere than at D.

The part of the ordinate intersected between BB' and ADC' represents the oxygen in the bath in excess of that taking part in the reaction FeO + C = Fe + CO. These intercepts are plotted separately in Diagram II (Fig. 2).

The ideal consists in dead-melting to "condition D," that is:

Oxygen D, ALL in course of removal by reaction FeO + C;
Carbon D';
Temperature D''.



The ordinates are oxygen in excess of that taking part in the reaction FeO + C = Fe + CO, as obtained from, and explained under, Diagram I.

Effect of Adding Lime.

FeO	— SiO_2	Slag	$\frac{CaO}{FeO}$	— SiO_2
FeO	— C	Metal	FeO	— C
Before adding lime.			After adding lime.	

It is evident from this explanation of the action of lime that when, as often happens, the nature of the charge and other conditions are such that the early addition of lime is not essential, it is sufficient to add lime at a late stage, in approaching the dead-melted condition. The above described reaction then occurs, and a satisfactory dead-melted condition is attained in from twenty to sixty minutes, according to various other circumstances. In this way the exposure of the banks to possible damage from careless handling of the lime is minimised.

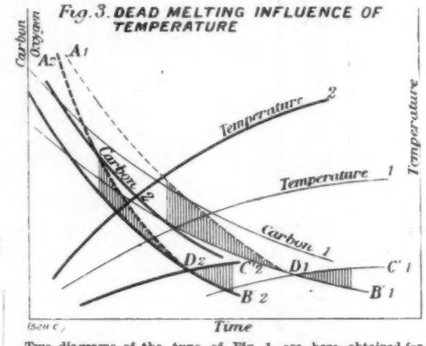
It is necessary, in considering the above, to realise that the whole process is an oxidising one, and that the oxidising action never ceases during normal working. Thus the expression "dead-melting" is a relative one, and it is important to inquire what happens if the "dead-melted" condition be overstepped in any way. At this stage the reaction may be comparatively slight—for example, a drop of 0.01 per cent. carbon in a quarter of an hour—or rapid—a drop of three to five times as much—yet with satisfactory results. Reference to Fig. 1 will show what may happen next: we may in the extreme case have the rate of production of iron oxide by furnace atmospheric oxidation greater than the rate of its decomposition by carbon, and the carbon being low, the metal becomes increasingly charged with iron oxide. It is probable that the solubility of iron oxide in the metal increases slightly as the temperature rises and as the carbon decreases beyond some very low figure (Fig. 4). It is further probable that the solubility of each of the gases decreases continuously with rise of temperature from the melting-point, but drops suddenly in solidifying, as shown qualitatively in Fig. 4 for oxygen as CO.

Reference to Fig. 2 will now show in a simple form one of the principal features extracted from Fig. 1, namely, the curve of excess oxygen present—the oxygen in the bath as a whole which is in excess of what can be removed by the reaction with carbon.

In Fig. 3 the corresponding complete diagrams (such as Fig. 1) for two different temperature curves are given, with summary of several of the most important effects of adopting the higher temperature curve.

We can now see the several conflicting factors which enter into the proper deoxidation at this stage—the chances of undergoing it on the one hand, and leaving the steel considerably oxidised, though not markedly wild (this is the commonest error), or, on the other hand, overdoing it and producing wild steel, which is not in all circumstances fully cured by the use of deoxidisers. Thus, for example, it is useless to make a rigid practice (as the author has known done) of running the carbon down to 0.07 per cent. to 0.09 per cent. in all casts, with practically no reference to "condition," in other respects, and then to imagine that this is dead-melting because a lot of "pigging-back" was done. At 0.09 per cent. carbon the bath is usually "underdone," because a relatively high temperature is required to dead-melt at this carbon. Incidentally, a relatively slight excess of temperature would, under these circumstances, lead to wildness; but with care in approaching 0.09 per cent. carbon there is no difficulty in obtaining a good dead-melted condition at this carbon if necessary.

Another extreme instance is the attempt to catch the carbon at say 0.45 per cent. carbon, including obtaining three or four successive samples in half to one and a half hours, all analysing 0.45 per cent. carbon. This can be done, and sometimes is—approximately—but it is not to be imagined that this is properly "dead-melting." The bath has in such a case been held quiescent by its coldness, and the diagrams show that, under these circumstances, its oxygen content is higher than it should be before going on with the additions. Incidentally a relatively great excess of temperature, and even a first addition of lime, need not in this instance do worse than cause the fall of the carbon to 0.25 per cent. to 0.30 per cent. in one to one and a half hours and produce a good dead-melted bath. It will be realised that to a great extent the diagrams here presented must be only of a qualitative nature. They have, however, been derived from a great variety of experiments arranged to test the various points at issue. It will be seen, for example, that a consequence of Fig. 1, as of some of the above-expressed conclusions, would be, that if the temperature of the bath could be promptly raised whilst keeping the other conditions (especially oxidation and carbon addition) as stationary as possible, an underdone cast could be dead-melted or a dead-melted cast made wild. This is not, however, very well illustrated in the acid furnace, owing to the relative slowness of the heating, but the action is evidently exactly what should be made fullest possible use of, as mentioned in the foregoing instances. On the other hand, it is possible to study this action in the reverse way—that is, by prompt cooling of the bath. The means by which the author achieved this was the addition of fairly massive scrap steel of similar class to the bath. If this be done when an ideal dead-melted condition has been obtained, then as soon as the scrap addition is melted and mixed in, the bath shows the usual signs of coldness.



Two diagrams of the type of Fig. 1 are here obtained for the two different temperature curves 1 and 2. The other corresponding curves are marked throughout respectively 1 and 2. Otherwise the notation is as in Fig. 1.

D1 and D2 are the two resulting ideal dead-melting "conditions." The advantages of the higher temperature curve 2 are seen to be: greater speed of working; greater probability of reaching "condition D" at all; greater definiteness of "condition D," &c., as discussed in the text.

Again, if a good dead-melted condition be exceeded, and by pushing the temperature too high in relation to the other conditions a somewhat wild bath is obtained, the addition of the correct amount of scrap restores a perfect dead-melted condition.

Here the author feels obliged to issue a word of warning. It must not be imagined that he is advocating the indiscriminate addition of scrap for the control of condition in dead melting; to do so might cause more mischief than it would remove. Further, he does not make a sweeping claim of novelty in adding scrap (or anything else) to the bath, which has often been done by others, especially amongst the final additions; but he is not aware that it has been used in exactly the way above described in the study of the essential "condition" of the bath. It is one of the most valuable methods of study of which the author is aware, and it has assisted him in arriving at a decision as regards several of the more obscure features of the subject.

It is necessary to draw attention to another important consequence of the above views. In the attempt to end the oxidising stage satisfactorily, it is from the practical point of view necessary not only to minimise the oxygen present in the system, but also to do so with the carbon content within reasonable limits of a desired figure—which varies considerably with the circumstances. The nature of the running equilibrium has been indicated, and it is therefore evident that some careful choice must be exercised in regard to the controllable excesses which

* Paper read before the Iron and Steel Institute, September 21, 1917.

* Journal of the Iron and Steel Institute, 1917, No. I, page 99.

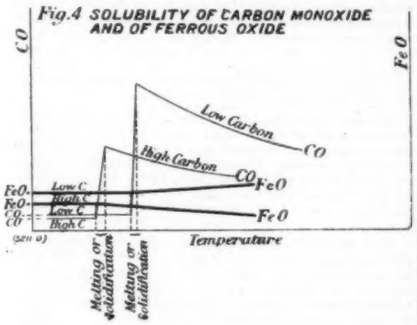
may occur. In this respect we have to notice chiefly temperature, carbon and iron oxide. The influence of temperature has already been discussed. The important point as regards carbon and iron oxide is to choose correctly the carbon content at which to cease oreing, so that in view of all the particular circumstances then prevailing (approximate ore content of the bath, the relative keenness of working of the furnace, the general nature and volume of the slag, &c.) dead-melting will be achieved at a convenient carbon content.

Deoxidisers.—It may be, and sometimes is, asked: What is the advantage of such great care in deoxidising the bath by dead-melting when deoxidising additions are afterwards to be used. The reply is that the author has found by wide and careful experiments that no one deoxidiser will alone thoroughly deoxidise steel, and that when two or more deoxidisers are used, each has an effect, and the combined effect is greater than if one of them be omitted; in fact, the more the better, if they be good deoxidisers. The fact that carbon alone is not sufficient to deoxidise steel demonstrates the truth of this conclusion. The actions of the deoxidisers are not quite identical. Thus we have carbon, which forms a gaseous product (CO, possibly soluble in the metal, but largely passing off) with the oxygen present, and a soluble carbide with the metal.

Manganese, to the extent it is commonly used, dissolves in the metal in some form and produces manganese oxide, which unites with avidity with silicates, but which is at most slightly soluble in the metal. Incidentally also, a part of the manganese unites with sulphur, producing an insoluble sulphide.

The action of silicon normally resembles that of manganese—it is partly dissolved in some form, and it produces insoluble silica, whose assimilation by the silicates and basic oxides is not so ready as the combination of MnO with the silicates.

Fig. 4 SOLUBILITY OF CARBON MONOXIDE AND OF FERROUS OXIDE



Aluminium, in the amounts used, enters only to a very slight extent into the metal, and produces an oxide which frees itself fairly readily from the metal, but which does not readily associate itself with the other non-metallic matters.

From the point of view of partial pressures of solutions and balanced reactions, the greater simultaneous action of deoxidisers seems fairly comprehensible. Despite, for example, the presence of some manganese in solution in the molten metal, a certain amount of FeO and CO still remain dissolved and even unacted upon by Mn.

Upon adding silicon to the system the saturation pressures of FeO and CO fall still further, but not to zero.

There is similarly a drop upon each deoxidising addition, assuming that at least a slight excess of deoxidiser is used.

Deoxidisers. Temperature Effect.—The exact saturation pressures of the residual FeO and CO depend upon the temperature. The heat balance shows that in the presence of excess deoxidiser the pressures will fall with higher temperature. This the author has verified in numerous experiments. In other words, the deoxidisers are more efficacious the higher the temperature of the metal at the time of their addition. The effect of higher temperature and time in giving the entangled products greater opportunities to float to the top is generally recognised. Here, again, high temperature is advantageous, but it is, as in dead-melting, necessary to beware of the renewal of too oxidising conditions in attempts to raise the temperature at this stage. The casting conditions which have to be met are, however, usually permitted to dictate the temperature control more and more as the end of the process is approached. Throughout the process is admittedly full of such compromises, but the present is a plea for ideals accompanied by suggestions as to how to attain them, and even in the last-mentioned stage the author much prefers to see it attempted to get the maximum deoxidation as stated, followed by temperature control, or even by modification in the details of casting, to obtain the required ingots.

Casting.—Approaching the casting stage, the processes have more and more in common, but at the same time there is a greater variety in any event in the conditions to be met, in the size and form of ingot, &c., so that strictly metallurgical generalisations are not so readily applicable to the whole field. Only a few of these points will be touched upon in the present paper whose relation to the melting process proper is closest, and other features will be left until a future occasion.

Much good steel is more or less ruined in "the pit" in casting, and the author has given much importance to the improvement of execution at this stage.

Three of the principal types of original defects in steel are rokes, non-metallic inclusions, and pipe. Rokes which do not contain siliceous matter may arise in mechanical ways in worked steel, but more generally they arise from blowholes in the ingot. The means which have been outlined above for minimising oxygen are the prime means for obviating rokes arising from blowholes. Blowholes, usually local in the ingot (that is, not related to the general anatomy of the ingot) can also arise through wrong design of ingot, bad surface or facing of mould, &c.

Non-metallic inclusions arise in various ways: (1) Entangled slag, and silicates or MnS in suspension in the bath and carried over to the ingot; (2) silicates formed *in situ* in the ingot by a continuance of the deoxidising action and aided by oxidation of the steel by air during its passage into the mould: (3) MnS formed *in situ* by continuance of the action of Mn in the ingot during solidification; (4) fluxed refractory fittings, especially runner bricks.

The influence of high temperature and time in lessening (1) has already been noted. As regards (2) and (3), there is a slight advantage in hot steel; (4) is a strong argument for avoiding bottom running if possible.

Steel made on the lines indicated will have the greatest tendency to piping, but it is always possible to minimise this tendency systematically. This depends essentially upon the adoption of conditions conducive to efficient feeding during solidification. These include the proper proportioning of diameter to length of ingot and means of hindering the cooling of the upper part; these means are of several kinds, and their choice largely depends on cost in relation to the selling value of the steel. Refractory lined heads, and ingots wide end uppermost, are the simplest and most direct methods.

The full advantages of casting ingots wide end up are, for the greater range of ordinary work, best obtained from a mould standing on a loose bottom plate, preferably with a well for sizes over three tons or so, containing a loose but fairly massive piece of scrap plate for the stream to strike upon first. If this loose piece be adopted, it is essential that every loose piece absolutely should be identified afterwards for each ingot, since sometimes I have known this plate, if too light, to be washed up into the ingot and cause trouble.

In conclusion, the main objects of the present paper have been to give critical consideration to the principal features of the acid open-hearth process which affect the production of a sound, clean ingot. Naturally attention has been mainly centred upon the most predominant of the features, deoxidation. The means of carrying these principles into effect in the process have been indicated—ideal dead-melting and the proper use of lime and of deoxidisers. Finally, brief consideration has been given to conditions which must be observed in order to utilise the full advantage of the high degree of deoxidation obtained, and in order to minimise the piping to which such steel is otherwise subject. It is seen that the author's general preference is for ingots top cast, with the wide end uppermost, and suitably fed, as for example, by refractory heads, or special methods.

Experiments contributing to the conclusions here recorded have been made in many works. The author is thus indebted to many firms, and is grateful for courteous permission to mention amongst them Messrs. Cammell Laird and Co., Limited, Sheffield; Messrs. Taylor Bros. and Co., Limited, Leeds; and Messrs. John Baker and Co., Limited, Kilnhurst, near Sheffield.

THE PANAMA CANAL.—According to *The Panama Canal Record* the total number of ships making the transit of the Canal during the fiscal year ended June 30, 1917, in sea-going traffic, was 1,876. In the fiscal year 1916 the total was 787; in 1915 it was 1,088. The aggregate gross and net tonnages of the 1,876 ships in the year 1917, according to the rules of measurement for the Panama Canal, were 8,530,121 tons and 6,009,358 tons respectively. The cargo carried through the Canal amounted to 7,229,255 tons of 2,240 lb.

ALLOY FOR SHIPS' PROPELLERS.—*The Scientific American* says that an alloy which has proved very satisfactory for ships' propellers is turbadium bronze. This alloy is said to have a tensile strength of 35 tons to 42 tons, with an elongation of 14 per cent. to 20 per cent. on a 2-in. test piece, and it is not appreciably corroded by sea water. According to *The Chemical News* its composition is, approximately, copper, 48 per cent.; zinc, 45 per cent. to 46 per cent.; tin, 0.5 per cent.; lead, 0.1 per cent.; iron, 1 per cent.; aluminium, 0.2 per cent.; manganese, 1.75 per cent.; and nickel, 2 per cent.

THE LATE MR. CHARLES LATHAM.—We regret to have to record the death, on September 27, of Mr. Charles Latham, Professor of Mining at the University of Glasgow since 1907. Professor Latham was born at Birkdale, Lancashire, in 1868, and received his education at Wigan High School, Rivington Grammar School, and the School of Mines, Wigan. He was then articled to the Moss Hall Coal Company, Wigan, of which company he acted as assistant general manager from 1891 to 1893. He was then director of mining at University College, Nottingham, from 1893 to 1902, and subsequently, from 1902 to 1907, Dixon lecturer in Mining at the University of Glasgow, and Examiner in Mining at the University of Manchester, and from 1907 Professor of Mining at Glasgow University. Professor Latham was a member of the Institute of Mining Engineers. His loss will be greatly felt by his colleagues and students.

REPAIRS TO FACTORY CHIMNEYS.*

By THOMAS HENRY WARD, Assoc.M.Inst.C.E.

THE author recently had to deal with the problem of repairing a chimney 163 ft. in height, situated at Giridih, in the East Indian Railway collieries, where steeplejacks are not available. The repairs required to be done were extensive, involving the pointing of two principal cracks, at opposite ends of a diameter, which ran nearly the whole height; smaller cracks also required attention. In short, the chimney (which serves a battery of Simon-Carvés by-product coke ovens) was in a bad state, and it was clear that it required clamping from bottom to top if it were to be rendered capable of withstanding the heavy winds which prevail in these latitudes. Unless a scaffold could be devised on which workmen could safely stand to work, it was very questionable whether

Fig. 1.

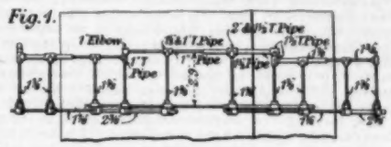


Fig. 2.

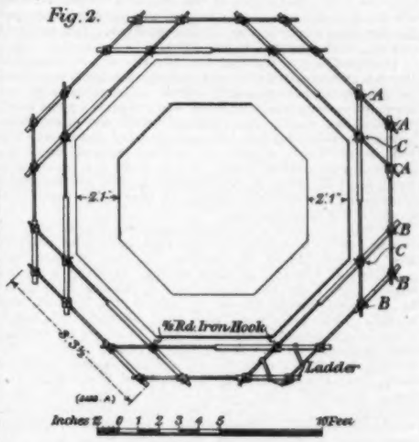
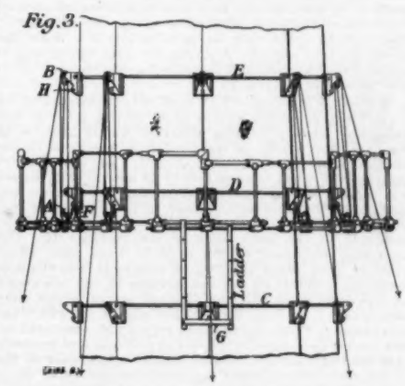


Fig. 3.



men could be found who would undertake the work: in which case the usual costly alternative of indenting on England for experts would have been necessary.

In these circumstances the author evolved the plan described below, which was successfully carried out. The chimney was octagonal in form, having the external dimensions: radius of circumscribed circle at bottom 7 ft. 5 in., at top 4 ft. 3½ in. The essential points of this plan are two:—

1. A scaffold which automatically adjusts itself to the varying diameter of the chimney when going up or coming down.

2. Points of support, on the chimney itself, at an accessible distance above one another, from which the scaffold can be suspended, and raised or lowered.

In the case in question the octagonal scaffold was made up of alternate pairs (1 ft. 6 in. apart) of galvanised-iron gas pipes, 2 in. and 1¼ in. in internal diameter, fixed rigidly together at each angle of the octagon, each pair being 2¼ in. apart vertically. At alternate angles the 2-in. diameter pair faced, in the same plane, the 1¼-in. diameter pair, the latter passing into (and right through when the scaffold was at the top of the chimney) the 2-in. pipes. Similarly the pipes forming the fence consisted alternately of 1-in. and 1¼-in. diameter

* Paper selected for publication in the Minutes of Proceedings by the Council of the Institution of Civil Engineers.

galvanised-iron pipes, the one passing into and through the other. (Figs. 1 to 3.)

The pipes were connected at each of the eight corners by passing them through suitable holes in brass castings, which, in order to hold the pipes firmly, were bored ½ in. larger in diameter than the outside diameter of the pipes for a distance of 1½ in. on either side of the transverse centre-line of the casting—that is, within ¼ in. of the outer ends. These recesses were filled with white metal, introduced through holes drilled through the top and middle walls. Four of these castings were required at each corner (A, A, A and C at one corner, and B, B, B and C at the next), the three forming the outer side being tapped at the top to receive the uprights to support the fencing (Fig. 1), which also was entirely formed of galvanised iron gas pipes. The horizontal (top) members were, at alternate corners, 1¼ in. and 1 in. diameter, so that the latter could pass into the former when the scaffold was collapsed or expanded. This fence was rigid and reliable; the inner casting C (Fig. 2) had, at the top, a pair of ears A (Fig. 3), through which a pin could be placed on which two pulleys, forming the bottom set of the two-sheave blocks by which the scaffold is raised and lowered, were fixed.

The deck of the scaffold consisted of light 12-in. planks secured by hook bolts to the pipes. The hook bolt at one end was permanently tightened up; at the other end the plank had a slot of the required length, so that the hook could be tightened up at the positions required to suit the varying size of the scaffold. (In practice the nut of this hook was left slack.)

The clamping of the chimney consists of 1-in. diameter tie-rods, which pass through castings set back and fixed in the brickwork at each corner. These castings are fixed by cutting the wall back 3 in. to give a good hold. With a less depth the castings could not have been placed in position and left unsupported before the tie-rods were fixed, which would have caused some inconvenience. When fixed, the tie-rods are practically flush with the face of the brickwork, and are arranged alternately above and below, so that they may pass through the same casting.

It was by means of these castings, which will, of course, carry a heavy vertical load, that the scaffold was secured, raised or lowered. A pair of ears was provided at the top of each casting, carrying a pin to which were fixed the upper pair of wheels B (Fig. 3) of the two-sheave blocks on which the scaffold was raised. This pin, with the two wheels, was easily removed to the next higher casting. A single ear, or lug, was provided at the lower end of each casting. By means of a D-link and short chain the scaffold could be hung from the ears H (Fig. 3), hooks of ⅝-in. round iron being provided, fixed close to each of the inner brass castings C (Fig. 2), into which a link of the short chain could be hooked. These hooks were exactly opposite each angle of the chimney, the shanks being bent sideways to fit the castings and then turned round each of the smaller diameter pipes close up to the castings C. The scaffold could thus be held in position while the workmen were engaged in fixing the next higher ring of castings and clamps, and transferring the pin and upper pair of wheels, B (Fig. 3).

Method of Working.—The scaffold was assembled on a platform arranged at the level of the base of the octagonal portion of the chimney which had to be clamped, and a ring of eight castings was fixed in the brickwork at a convenient height. In the case in question the rings (clamps) at C, D and E (Fig. 3) are 4 ft. apart, and it will be convenient to describe the position of the scaffold as shown in the figure, hanging on the castings of the ring D, attached by means of the chains F to the lower ears of the castings H. The horizontal members of the scaffold were then about 12 in. to 14 in. below this ring of clamps D, and the men could easily reach to cut the recesses in the brickwork for the castings in the ring E, next above, which were thus about 5 ft. from the scaffold planks on which the men stood. When the castings were fixed, cemented in, and the tie-rods (clamps) placed in position and properly tightened up, the pins, carrying the upper pair of the two-sheave blocks, were rigged up in the ears, B, of the castings, and the lower pairs in the jaws A. The rope always remained reeved in these blocks, so that the above operation was a very simple one. In the case in question the falls of the ropes were carried down to the ground, and men were employed (the gangs working on the coke bench alongside were always available for 10 minutes or 15 minutes, so that it was unnecessary to make any mechanical arrangement, or to employ special labourers) to raise the scaffold until it reached the same relative position below the ring E which it had occupied below the ring D. The scaffold was then made fast to the ring E as before, by means of the chains F, so that the castings in the next ring above, E, could be fixed. This process was repeated until the top of the chimney was reached, and the men were always working on a firm scaffold inside a fence.

Instead of taking the falls of the ropes to the ground, the men on the scaffold might perhaps have raised themselves. This plan was not tried, and would certainly not be so safe as the one adopted. The sheaves were made of brass, and were about 3 in. in diameter, and a six-strand, nineteen-wire, hemp-cored, flexible galvanised-steel rope, ¾ in. in circumference, was used, which had a breaking strain of 2¼ tons.

The batter of the chimney, 1 in 40, kept the eight sections of the scaffold close to the chimney under gravity. In raising or lowering the scaffold eight men, sitting on the scaffold, one at each corner, were required to fend off, so that the projecting ears of the corner castings could be safely negotiated.

Access to the scaffold was gained by means of a double ladder, or cage, hung from the scaffold and clamped to the pipes forming one of the "rigid corners." This ladder is shown in Fig. 3, in the centre, and in Fig. 2. It extended about 4 ft. below the scaffold, the two sides being held together at the bottom by a bow of flat-iron, G, on the outside. The men and materials were pulled up by a steam winch, the rope being taken up to a snatch-block hung from the ears of one of the castings, and brought down through the centre of the rigid corner of the scaffold where the ladder or cage described above was fixed. The rope was passed under a snatch-block at the ground-level, so that it was guided through the ladder. A man, when pulled into the ladder, could easily climb up on to the scaffold. An ordinary sling could have been used for the men to sit in, but in the case in question special harness was used. This consisted of a leather belt 6 in. wide attached to each side of a strong oblong iron link fixed in front of the rider, to the top end of which the rope was attached, and to the lower end two strong leather straps which were buckled under the thighs. The rider thus had both hands and legs free to enable him to push himself clear of the wall, against which gravity tended to keep him. The material sent up was kept clear of the chimney by attaching a tail rope, by means of which a man on the ground could guide the load. The masons employed on the coke ovens did all the work on the chimney, and no extra wages were paid to them. The clamping was, in fact, done in the intervals when the men were not required for their legitimate duties on the coke plant.

It may be mentioned that the falls of the eight ropes used for raising the scaffold were in each case taken under a pulley or snatch-block at the ground-level, so that the men could pull to greater advantage, and the ropes could be made fast to wooden bollards fixed in the ground.

The scaffold could, it was found, be raised into position for a new ring and made fast in about 15 minutes. Two masons only could be spared at the same time from the staff working on the coke ovens, and they could cut out the brickwork for, and fix the eight castings forming, a ring in about two days.

The author's experience goes to show that, as a chimney must sooner or later require repairs, by far the best plan is to clamp it when it is being built. This plan would generally prevent the formation of serious cracks, and as a system of clamping on the lines described above could be adopted, the climbing of the chimney at any time could be very easily accomplished. The author is now building a chimney, 100 ft. in height, on this principle. The chimney is a square one, as this simplifies the construction and manipulation of a collapsible scaffold. It is being built from the inside, without any outside scaffolding, in the ordinary way, but clamps 5 ft. apart are being put in position, so that the chimney can be climbed at any time. One advantage of clamping as the chimney is being built is that the clamps can be spaced at a greater distance apart, since the only operation which will have to be performed while standing on the scaffold will be the putting in, or taking out, of the pins supporting the upper pair of wheels of the two-sheave blocks. This can be effected at the full stretch of a man's arms, or by standing on something. When the scaffold, in the case described, reached the topmost position, it was found easy to get past the cornice right on to the top of the chimney by using a light ladder.

It may be added that a collapsible scaffold of light joists, or angle bar, could be constructed in various ways to meet the conditions laid down. Perhaps the easiest way of using these materials would be to connect the contiguous corner segments of the scaffold by means of two pairs of links, articulated below, which would provide for the expansion and contraction of the scaffold. A very light scaffold could be made in this way, which would suit chimneys with a considerable range in dimensions; but the difficulty of making strong and rigid connections to light sections for the links would present itself. On the whole the simplest plan appears to be to use pipes.

The author is indebted to Mr. N. P. Fielding, engine-wright, East Indian Railway Collieries, for assistance in working out the details of the scaffold and for preparing the drawings.

Gas-Driven Motor Vehicles.—A committee appointed by the British Commercial Gas Association has been investigating the use of gas as a substitute for petrol on motor vehicles. They state that a successful method of doing this has been worked out by Messrs. Barton Brothers, of Beeston, who use a flexible balloon-like gasholder carried on the roof of the vehicle. These holders are made in a range of sizes of from 150 to 500 cub. ft. capacity each. The gas is stored in these under a very low pressure, and hence, in spite of the large bulk of the holder, only enough gas for a short run can be carried. As against this drawback must be counted on the credit side the ease and rapidity with which the holder can be replenished, its cheapness and its light weight. The alternative plan of carrying the gas compressed into steel cylinders is said to be impracticable in the present condition of the iron trade. Such cylinders are in daily use for other purposes, the usual maximum storage pressure being 120 atmospheres, though 200 atmospheres have been adopted in some cases on the Continent. The lower of these pressures has been proposed for vehicle work, but the cost of compression is high, and close supervision would be necessary in dealing with cylinders so highly stressed. The gas is, moreover, it is stated, liable to deteriorate when stored under these extreme pressures. The committee consider, therefore, that there are better chances of success with a storage pressure not exceeding 20 to 25 atmospheres.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

Middlesbrough, Wednesday.

The Cleveland Iron Trade.—The market is strong, with a brisk business doing in Cleveland pig-iron in connection with the home October allocations, whilst there is no abatement in foreign demand. All kinds of Cleveland pig-iron are plentiful, and expansion of trade with our Allies is looked for. Foundries appear to be entering on a busier period, and the opinion is expressed that they are likely to absorb all the iron available. Deliveries are mainly from current production, difficulty being experienced in lifting stocks owing to shortage of labour. Consumers of forge-iron are well bought, and new business in this branch is quiet, but large supplies are being taken up in fulfilment of running contracts. For home consumption No. 3 Cleveland pig-iron, No. 4 foundry, and No. 4 forge are all quoted 92*s.* 6*d.*, and No. 1 is 96*s.* 6*d.*; and for shipment to the Allies No. 3 is 102*s.* 6*d.*, No. 4 foundry 101*s.* 6*d.*, No. 4 forge 100*s.* 6*d.*, and No. 1 107*s.* 6*d.*

Stock of Cleveland Pig-Iron.—The stock of Cleveland pig-iron in the public warrant stores still stands at 1,137 tons—all No. 3 quality—no change having been recorded since July 7 last. There are now warrants in circulation for only 500 tons of iron.

Hematite Iron.—Little news of importance is ascertainable concerning the East Coast hematite branch of trade. Some little improvement in the situation is noticeable, but conditions continue stringent. Under the official system of distribution regular and adequate supplies are still going forward to inland customers, but exports are on a very limited scale. A fair number of home transactions are reported from time to time, but new foreign business is very difficult to arrange, though every effort is made to meet urgent needs of our Allies. Rather better tonnage facilities are looked for, but with a large volume of applications for export licences awaiting consideration, renewal of buying to any extent is not anticipated. Nos. 1, 2 and 3 are 122*s.* 6*d.* for home use, and 141*s.* for shipment to the Allies, the export quotation being subject to addition of excess ore freights charged by neutrals above the parity.

Production of Pig-Iron.—The output of pig-iron has been reduced by the blowing-out of a furnace which has been running on Cleveland pig-iron at the Tees Furnace Company's works. This reduces the number of furnaces in operation on the North-East Coast to 75, of which 33 are making Cleveland pig-iron, 28 are turning out hematite, and 14 are manufacturing special kinds of iron.

Manufactured Iron and Steel.—All the finished iron and steel works are running at high pressure, and manufacturers are still disinclined to entertain ordinary commercial inquiries, as they are very fully occupied endeavouring to cope with the huge Government requirements and very heavy shipyard demands. The output of shipbuilding steel is now very large. Prices all round are very stiff. The following are among the principal market quotations to home customers:—Common iron bars, 13*l.* 15*s.*; best bars, 14*l.* 2*s.* 6*d.*; best best bars, 14*l.* 10*s.*; iron ship plates, 15*l.* 10*s.*; iron ship angles, 13*l.* 15*s.*; iron ship rivets, 19*l.*; packing iron and steel (parallel), 13*l.* 10*s.*; packing iron and steel (tapered), 15*l.* 15*s.*; steel bars (no test), 14*l.* 10*s.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel ship rivets, 20*l.* and upward; steel boiler plates, 12*l.* 10*s.*; steel joists, 11*l.* 2*s.* 6*d.*. steel strip, 15*l.* 10*s.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.*

Shipments of Iron and Steel.—Shipments of iron and steel from the port of Middlesbrough last month totalled 53,529 tons, of which 45,384 tons were pig-iron, 1,452 tons manufactured iron, and 6,693 tons steel. For the previous month clearances of pig-iron reached 59,083 tons, and for September last year shipments of pig-iron were returned at 44,969 tons.

Ironworkers' Wages.—According to the accountants to the Board of Conciliation and Arbitration for the Manufactured Iron and Steel Trade of the North of England, the average net selling price of iron plates, bars and angles for the two months ended August 31 last, was 13*l.* 13*s.* 4.43*d.*, as compared with 13*l.* 10*s.* 9.87*d.* for the previous two months, and under sliding-scale arrangements there is an advance of 3*d.* per ton on puddling, and 2½ per cent. on all other forge and mill wages, to take effect from the 1st inst.

The late M. Armand Puech.—We have to record the death, on September 16, of Monsieur Armand Puech, who was well known to water-works engineers in this country in connection with the treatment of turbid waters antecedent to sand filtration. M. Puech, who was in his seventy-second year, was closely connected with the cloth-weaving industry of Mazamet, in France, where large volumes of water required for industrial purposes were drawn from upland sources and were at times exceedingly turbid. Investigations by M. Puech, carried out over a considerable period, led to the development of the system of multiple filtration with which his name has been associated. For many years the system was chiefly applied to the clarification of water for trade purposes, but later, in collaboration with M. Henri Chabal, M. Puech had applied his methods to the purification of water for domestic use, and a large number of existing installations of open sand filters were modified by the adoption of roughing filters on the multiple system in place of settling reservoirs. M. Puech had also devoted much attention to the question of sewage treatment, and had designed several installations for the purpose of recovering indigo and other products used in textile industries from the waste water from factories.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—In every branch of the steel-making industry the most pronounced activity is the ruling feature, all classes of finished material being in urgent demand. Government requirements are still very much to the fore, and the entire output is as rapidly absorbed as produced. The necessities of the armies in the field are being met, but the demands made upon steel makers in connection with the Government's extensive mercantile shipbuilding programme are now heavier than ever, and the plate and section mills are running constantly to keep pace with this. Naturally, under the circumstances, little is available for export, or for the use of ordinary home consumers, a fact far from beneficial for trade, but all are fully aware that the material for war purposes must come first. In all cases where not officially fixed rates are firm.

Malleable Iron Trade.—Not only are malleable iron makers fully employed at the moment, but they have orders booked for many months ahead, the bulk of this work being on Government account, and principally for purposes of the war. Small sizes are much in request, and so also is shell discard steel, a quality which, until quite recently, was looked at askance. Times are changed, however, and customers unable to obtain certificates for iron or ordinary steel are very thankful when supplies of this quality are available for their use.

Scotch Pig-Iron Trade.—Pig-iron continues in very heavy demand, hematite in particular being much in request at the local steel works. Every effort is being made to speed up output, but some difficulties have been experienced in connection with the recent labour troubles. These, unfortunately, have affected work to such an extent that furnaces are not all in full blast. Government control of the production has been very helpful in that it has ensured the distribution of the output as most urgently required. Neither in export nor in ordinary overseas trade is much business being put through. Prices are firm and steady.

Iron Trade Wages.—There has just been intimated by Mr. John M. MacLeod, C.A., to Messrs. James F. Bishop and Owen Coyle, the joint secretaries of the Scottish Manufactured Iron Trade Conciliation and Arbitration Board, the statement that on examining the employers' books for July and August, 1917, he certified the average net selling price to be 14*l.* 9*s.* 5*d.* per ton. In consequence no change in the wages of the men falls to be made at this time.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

South Yorkshire Coal Trade.—With the interference of the Coal Controller in all matters of deliveries and contracts of manufacturing fuels there is not the same opportunity for open market business, and agents have little, if anything, to offer. There is a general expectation that an increase of price will soon be allowed in manufacturing fuel, for representations have been made to the Coal Controller that certain collieries are running at a loss due to the present limitation in selling prices and the increased cost of production, and it is understood that sympathetic treatment has been promised. The full output of the hard coal pits is required to satisfy contract accounts and Admiralty and Allied Powers. Inland gas works are receiving a large tonnage. Cobbles, nuts and slacks are all tightly held. The house coal position continues to be the cause of considerable anxiety to dealers and merchants, for the public are eager for supplies, which cannot be met out of present stocks. Quotations :—Best branch handpicked, 20*s.* 6*d.* to 21*s.* 6*d.*. Barnsley best Silkstone, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire best brights, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire house coal, 17*s.* to 18*s.*; best large nuts, 16*s.* 6*d.* to 17*s.* 6*d.*; small nuts, 15*s.* 6*d.* to 16*s.* 6*d.*; Yorkshire hards, 16*s.* 6*d.* to 17*s.* 6*d.*; Derbyshire hards, 16*s.* to 17*s.*; best slacks, 12*s.* to 13*s.*; seconds, 10*s.* 6*d.* to 11*s.* 6*d.*; and smalls, 8*s.* to 9*s.* per ton at the pit.

Iron and Steel.—The material market continues to favour sellers, for the abnormal demand enables them to obtain the limit price for all they have to offer. Basic iron is wanted in large quantity, the local buying being on a much greater scale than for some days, whilst the forge and foundry lines have once again found their former buoyant tone, and orders are coming to hand with greater freedom. The output of furnaces has improved as a result of the extension schemes, details of which have appeared in these notes from time to time. The steel demand remains at the highest possible level, and local works find a ready market for all they can produce, with the Government the most eager and sympathetic customer. The larger firms are carrying out progressive policies of extensions in order to expand their output. Ordinary commercial business is giving way more and more before the growing specifications for marine engineering and steel, tank parts, and the now highly developed aeroplane production. The latter is one of the branches in which dilution can be carried to the utmost lengths, for women are very capable in the innumerable delicate operations involved. File makers and saw makers find that the business with Russia is gradually on the decline. Italian customers are coming to Sheffield for more and more of their war work, and some big orders have recently been accepted from the Italian Government. Cutlers have not yet got over their disappointment with regard to stainless cutlery, but their representations to the authorities have been unavailing. In other lines cutlers continue to do a good trade with overseas customers. Plate makers have more Government work than hitherto, the call for copper bands being heavier than has usually been the case. In the latest mails the following indents from overseas customers have arrived: engineers' tools, saws, files, hammers, knives, machetes, springs, sheep shears, cutlery, plate, high-speed and carbon steel for Allied Powers, plane irons, hardware, and steel.

John Brown and Co.—The annual meeting of this company was held in Sheffield since these notes were last penned, and was noteworthy for the pronouncement of the popular and active chairman, Lord Aberconway. In a review of the position his lordship made many interesting remarks. He referred to the fact that they were doing enormous work with regard to ship-building of all descriptions, and wondered why the Government did not publish the actual figures of what we had achieved, for "I am certain that they will in no way be encouraging to the enemy." The firm, he said, had increased its shipbuilding capacity at Sheffield, and had doubled and trebled its shipyard facilities. All this meant extra expenditure, but the shareholders would reap the benefit after the war when he was sure shipbuilding would be the great and almost dominant trade for years to come.

The Sheffield Aeroplane.—Quite a pleasing function took place at Sheffield on Saturday last when, on behalf of the city, an aeroplane was presented to the Dominion of Newfoundland as a unit in the Imperial Air Fleet. There were many distinguished guests, both from the colonies and from the authorities in London, and some inspiring speeches were made. Sir David Henderson, who referred to the growth of the Flying Corps, pointed out that over two years ago he had to return from France to come and organise the air service supplies, and one of the first things he did was to come down to Sheffield to see if he could not get the manufacturers to reserve a portion of their steel output for aeroplanes. Since those days the supply had undergone a great change, for aircraft were not now regarded as an accessory to the fighting forces, but as a vital necessity. The output of steel for them had grown almost to a surprising figure, and they had not now to plead to be allowed to have supplies.

Messrs. Kayser, Ellison.—With a profit for the year of 38,670*l.*, this firm yesterday announced that a dividend of 20 per cent., free of tax, would be paid on the ordinary shares. This is the same distribution as last year. It has also been found possible to place 10,000*l.* to reserve and grant 5,000*l.* to the employees' benefit fund, which now stands at the handsome total of 36,232*l.* 7*s.* 8*d.*

Italian Visitors.—His Excellency Baron Mayor de Planches (High Commissioner in London for the Italian Government) and members of the Italian Mission in England, including Major Marquis Giulio Laureati, who made the magnificent flight from Turin to London, to-day concluded a short visit to Sheffield. They have visited the works of Messrs. Brown, Vickers, and Edgar Allen, and have been entertained by the Chambers of Commerce, the Lord Mayor, and leading industrial concerns. Sheffield's war output and resources have been a revelation to them.

THE LONGEST RAILWAY TANGENT.—The longest stretch of straight railway track in the world is said to be on the line from Kalgoorlie to Port Augusta, which constitutes the western branch of the East-West Transcontinental line of Australia. This long straight stretch begins near Goldea and continues for some 309 miles. The line of which this long tangent forms a part has a total length of 1,053 miles, for the most part with an extremely deficient water supply.

SILICA INCRUSTATION IN BOILERS.—An interesting case of a boiler failure, apparently due to the formation of a hard incrustation rich in silicates, is reported by Messrs. A. Goldberg and A. Barth, the latter chief engineer to the Saxon association for the supervision of steam boilers, in the *Chemiker Zeitung* of August 29, 1917. A series of boilers had for some years been installed in some works, and the boilers, which were in uninterrupted use, had been cleaned every three months. Under the pressure of work the cleaning had to take place at intervals of four or five months; then a crack developed in one of the boilers; the boiler was quickly repaired without much inquiry into the cause of failure, and then a second boiler failed, exactly in the corresponding spot. The boilers, which were combined with superheaters, were provided with two internal flues, which were corrugated in the front part; the cracks occurred in the straight flue near the corrugation. The examination proved that the iron was sound, but that the incrustation was locally abundant and of unusual composition. Ten samples were taken of the deposit, which was hard in some parts and muddy near the superheater end, and which varied locally in composition to an extraordinary degree. The carbonates were always low, about 1 per cent.; the lime (CaO) percentage ranged from 1 up to 24, the magnesia (MgO) percentage from 2.7 to 25, the calcium sulphate from 2 per cent. up to 83 per cent., the silica (SiO_2) from 9 per cent. to 59 per cent., and the percentage of iron and aluminium oxides (together) from 0.2 to 59. The iron did not come from the water, but from the boiler plates, which were corroded near the superheater end. The silica percentage was high in general, highest in the muddy portion. The hard scale, which seemed to be responsible for the local superheating and cracking of the plates, contained 36 per cent. of SiO_2, 2.4 per cent. of iron and aluminium oxide, 20 per cent. of CaO, 8.3 per cent. of MgO, 48 per cent. of $CaSO_4$, and had also a high percentage (6) of water of hydration. The feed water came from two sources, one of which was rich in silica; such feed water is not worth chemical softening sometimes, but may be used when the boilers are frequently cleaned. A further study on silicate boiler scales is to follow.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

Cardiff.—The two chief questions which are agitating the market are those relating to the supply of pitwood and to the transport of inland coals to south-western counties, on the basis of 20*s.* per ton at the pithead. In regard to the latter question it is pointed out that 20*s.* is totally inadequate and, in the majority of cases, a dead losing price. A serious view is therefore taken of the position by colliery owners. The legality of the Coal Controller's Order is questioned, and it is reported that immediate action is being taken to bring the Controller to a full knowledge of what his Order involves, and, if possible, to secure its modification, especially in view of the increased rates of wages which will now have to be paid to all classes of workmen. With reference to pitwood, better arrangements must be made to obtain timber in increased quantities and from other oversea sources. The position of the coal market generally continues unsatisfactory. There are daily stoppages at the collieries, and opinion is becoming more and more crystallised on the need for a better control of production. A suggestion was made some time ago that the situation might be eased by regularised stoppages of work, and it was then held that this would certainly be a preferable way to the haphazard conditions which now prevail. This matter is one for the decision of the Controller of Coal Mines.

Newport.—The arrivals during the week-end and the early part of this week have only slightly improved the tonnage position at the Newport market, but the improvement, following the restriction in output occasioned by Monday's stoppages, has been sufficient to permit a resumption of work at several pits in the Monmouthshire area, where it had been feared that the stoppages would have extended to two or three days. There is a good demand for inland coals. Pitwood is firm round about 70*s.*

Miners' Increased Wages and Price of Coal.—The advance of 1*s.* per day to colliery workmen over 16 years of age and 9*d.* per day to boys under that age is estimated to add about 4,250,000*l.* to the annual wage bill in the South Wales coalfield, and will naturally involve a considerable increase in the cost of production. As the recent prices were scheduled approximately on the then existing labour costs, they are now more or less inapplicable, and will need revision, or be supplemented by some arrangement between the colliery companies and the Coal Controller. The Admiralty collieries are perhaps secure of an increase in price, but those pits producing for inland consumption, and therefore under the provisions of the Price of Coal (Limitations) Act, will have to be separately treated. It is estimated that the recent increase in costs will necessitate an advance of anything from 1*s.* 6*d.* to 2*s.* 6*d.* per ton in the price of coal.

Colliery Examiners' Strike Threat.—In conformity with the tentative arrangement entered into between representatives of the coalowners and of those lower-grade colliery officials who are members of the South Wales and Monmouthshire Colliery Examiners' Association, at the Home Office last week, the notices of the latter to terminate contracts at the end of September have been suspended for a month, and a joint committee is dealing with the points at issue between the examiners or foremen (as they are generally known) and the employers. Hitherto colliery companies have regarded these grades as members of their colliery staff, and outside the control of the Coalowners' Association. Moreover, only just over 50 per cent. of these employees tendered notices, but, unfortunately, the history of the South Wales coal trade during the war has shown that it pays the workmen to use or threaten force to achieve their aims, and to secure the concession of demands which were not even formulated before the war. Hence the significance of the action taken at the present juncture by the Welsh colliery foremen.

AN ALL-TURBINE STEAMER.—A tank steamer is building in a shipyard on the Delaware whose engine-room, says *The Marine Journal*, New York, will present the novelty of having no reciprocating machinery of any kind. The propelling engine will consist of a low and a high-pressure turbine geared to a single propeller, a surface condenser with a centrifugal pump driven by a turbine, two centrifugal hot-well pumps also driven by a turbine, and a rotary oil pump for the turbine and gears, driven from the main gears. This is the first instance, adds the journal, where rotary machinery has been used throughout a ship, which marks an epoch in shipbuilding history.

GERMAN ACTIVITY IN SWITZERLAND.—We read in *L'Industrie Electrique* that the Berlin Allgemeine Elektricitäts Gesellschaft group owns, in Switzerland, over 275,000 h.p., for a capital of over 600,000,000 francs (24,000,000*l.*). The Siemens group has in Switzerland interests to the amount of 310,000,000 francs (12,400,000*l.*). Of 17 directors of a bank in Zurich, 8 are Germans and 1 an Austrian. The Bank for Electrical Enterprises, also of Zurich, has 16 Germans and only 7 Swiss. The Metallgesellschaft, Basle, has 9 Germans, as against 6 Swiss. German activity in Switzerland is confirmed by a statement made by Mr. H. C. Elliott, vice-president, at a meeting of the British Chamber of Commerce, Genoa, held on March 24; Mr. Elliott gave an account of a recent trip he took in Switzerland, which country, he said, was overrun by German commercial travellers; he added that at the German Consulate at Zurich, there were stated to be now 180 clerks, instead of 15 previously employed.

THE FERRO-CONCRETE SHIP "BETON I."

CONSTRUCTED AT THE PORSGRUND CEMENT WORKS, PORSGRUND, NORWAY.

(*For Description, see Page* 364.)

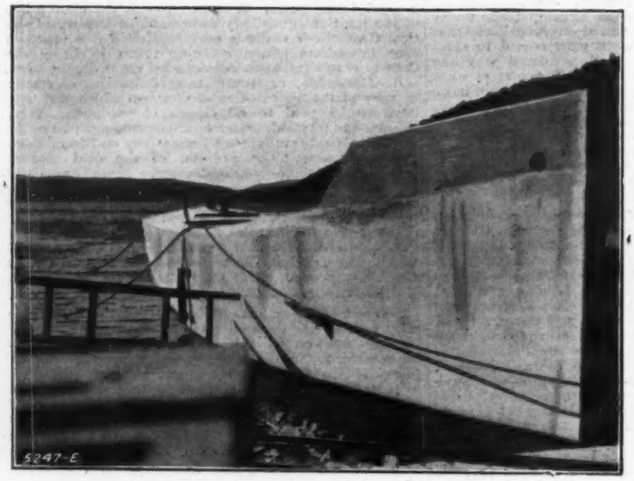


Fig. 1.

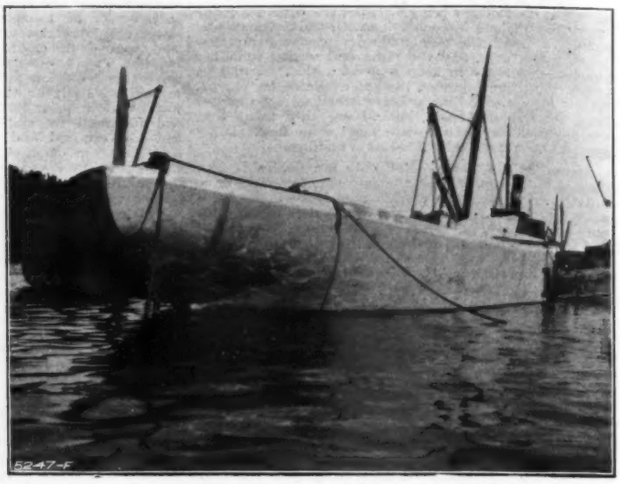


Fig. 2.

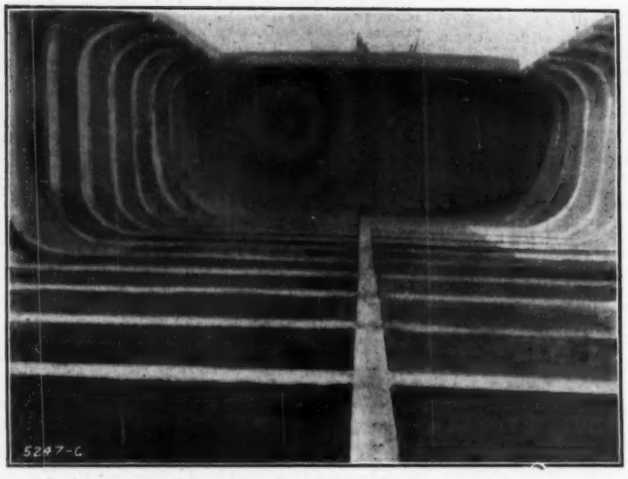


Fig. 3.

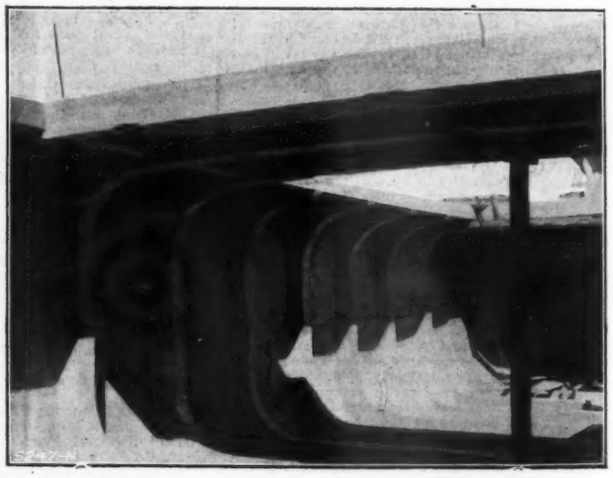


Fig. 4.

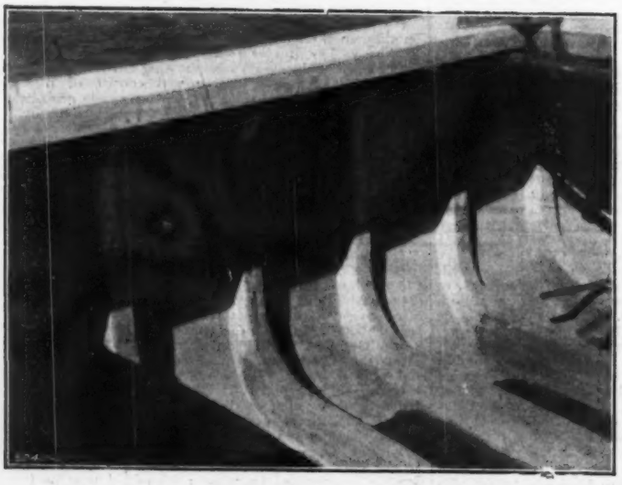


Fig. 5.

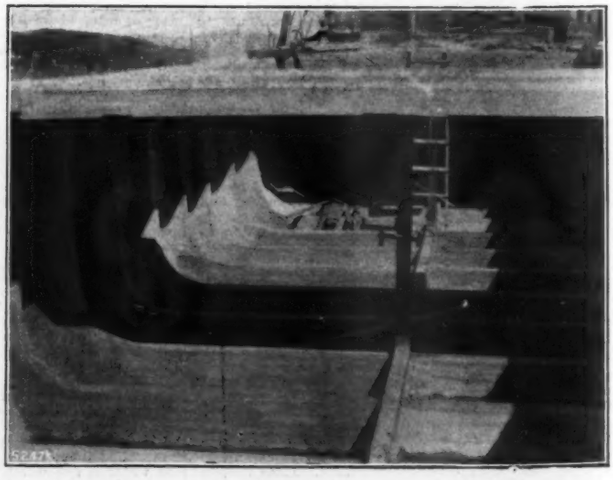


Fig. 6.

THE ARRANGEMENT OF MACHINE SHOPS.

THE WORKS OF MESSRS. MARSHALL, SONS AND COMPANY, LIMITED, GAINSBOROUGH.

(*For Description, see Page* 349.)

Fig. 180. Store for Finished Engine Details.

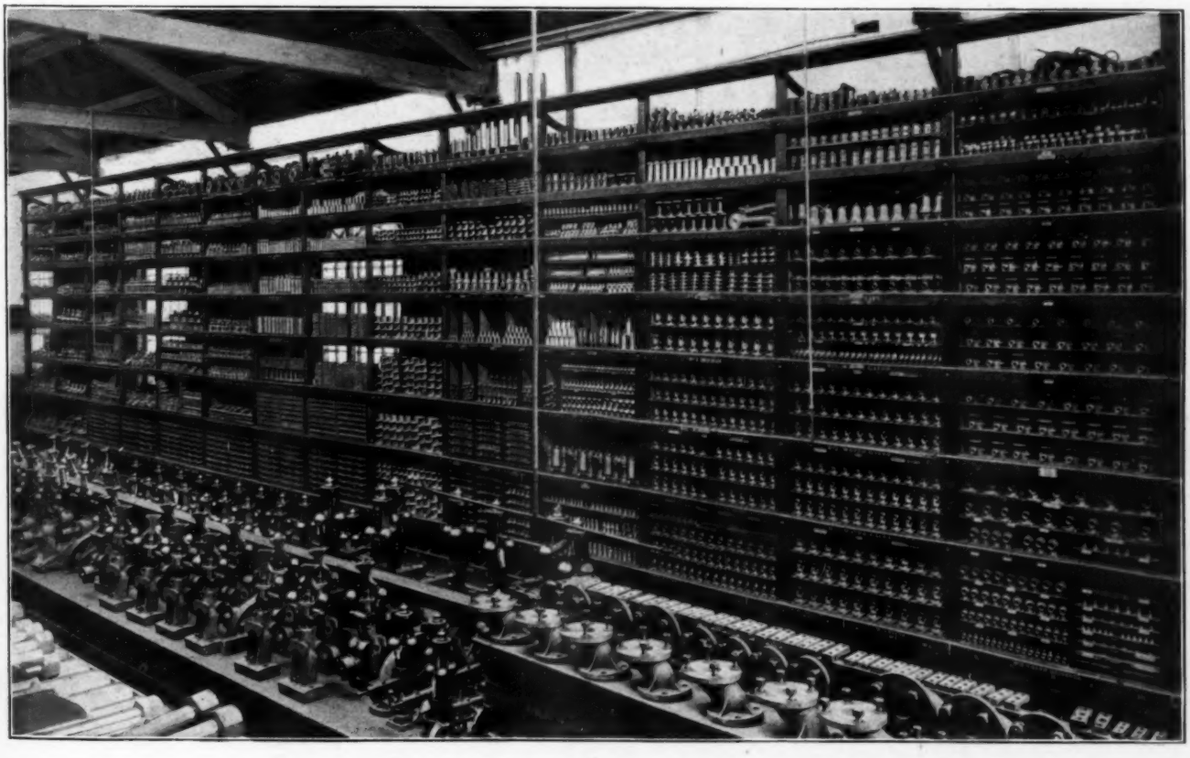


Fig. 181. Store for Brasswork, Governors, &c.

(*To face page* 352.)

THE ARRANGEMENT OF MACHINE SHOPS.

THE WORKS OF MESSRS. H. W. WARD AND CO., LIMITED, AT BOURNBROOK, BIRMINGHAM.

(*For Description, see Page* 349.)

FIG. 182. FLAT TURRET DEPARTMENT.

FIG. 183. ASSEMBLING LATHE HEADSTOCKS.

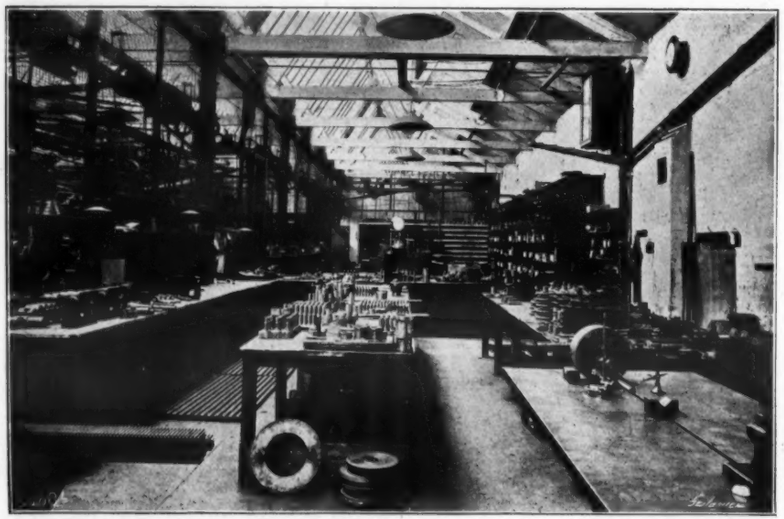


FIG. 184. INSPECTION ROOM.

FIG. 185. STORE FOR FINISHED PARTS.

(*To face page* 353.)

INVESTIGATION UPON A CAST OF ACID OPEN-HEARTH STEEL.

(*For Description, see Page* 355.)

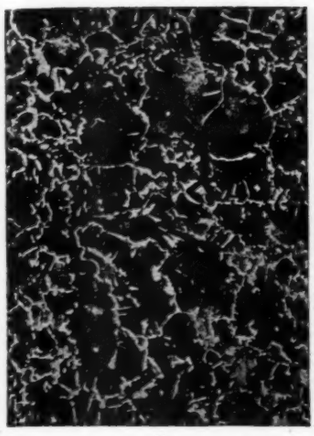


Fig. 1.—Ingot 6; Billet position 1 (bottom). Magnification: 50 diameters.

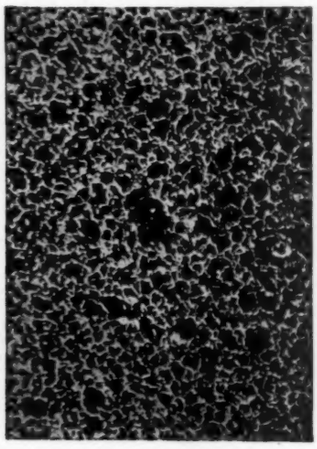


Fig. 2.—Ingot 9; Billet position 1 (bottom). Magnification: 50 diameters.

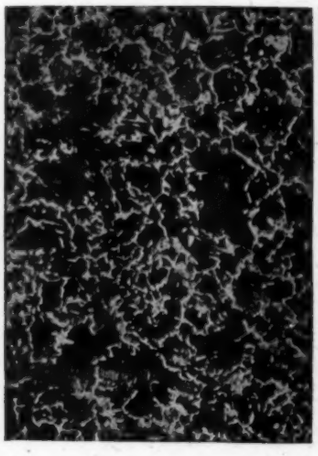


Fig. 3.—Ingot 12; Billet position 1 (bottom). Magnification: 50 diameters.

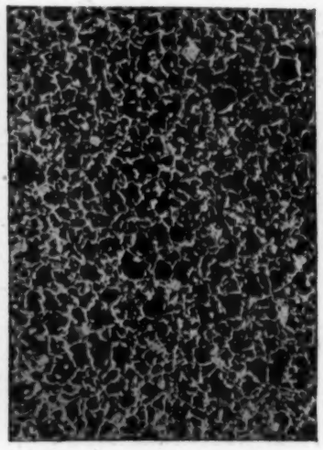


Fig. 4.—Ingot 14; Billet position 1 (bottom). Magnification: 50 diameters.

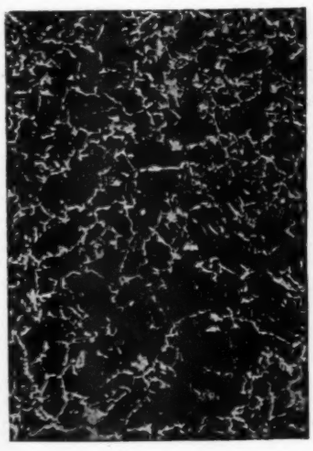


Fig. 5.—Ingot 17; Billet position 1 (bottom). Magnification: 50 diameters.

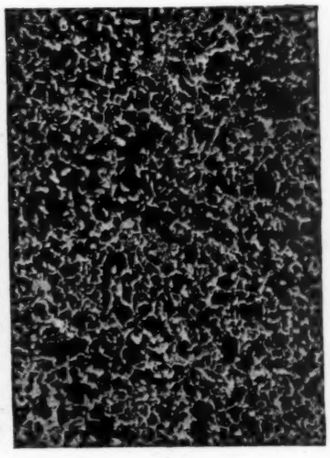


Fig. 6.—Ingot 2; Billet position 4 (middle). Magnification; 50 diameters.

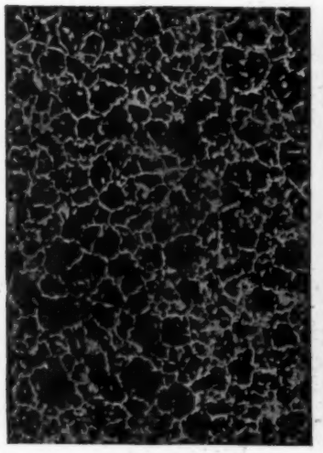


Fig. 7.—Ingot 7; Billet position 4 (middle). Magnification: 50 diameters.

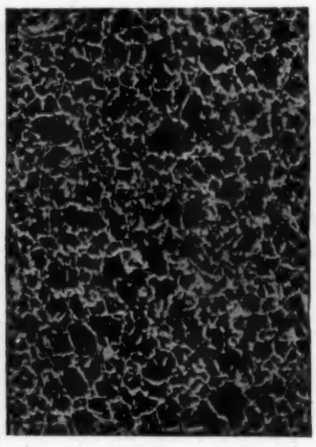


Fig. 8.—Ingot 10; Billet position 4 (middle). Magnification: 50 diameters.

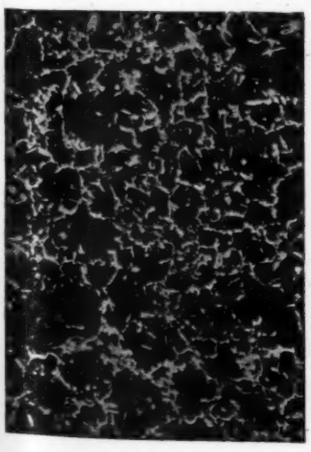


Fig. 9.—Ingot 15; Billet position 4 (middle). Magnification: 50 diameters.

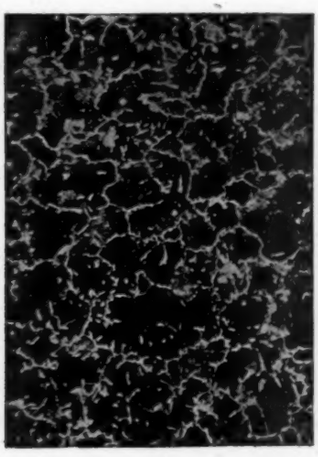


Fig. 10.—Ingot 20; Billet position 4 (middle). Magnification: 50 diameters.

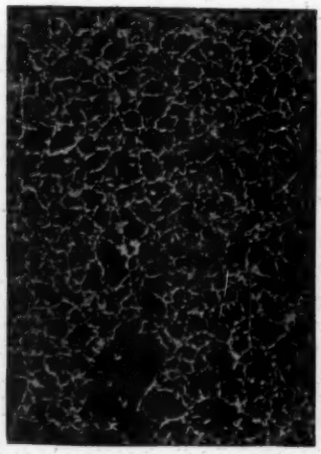


Fig. 11.—Ingot 7; Billet position 7 (top). Magnification: 50 diameters.

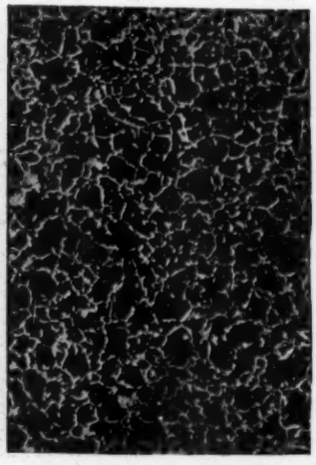


Fig. 12.—Ingot 8; Billet position 7 (top). Magnification: 50 diameters.

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(*To face page* 354.)

INVESTIGATION UPON A CAST OF ACID OPEN-HEARTH STEEL.

(*For Description, see Page* 355.)

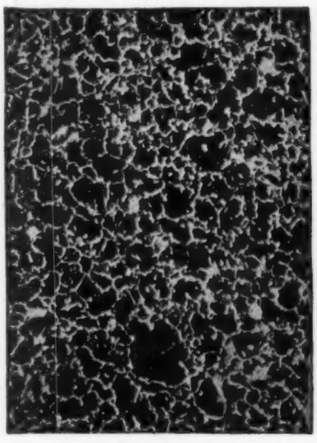

Fig. 13.—Ingot 9; Billet position 7 (top). Magnification: 50 diameters.

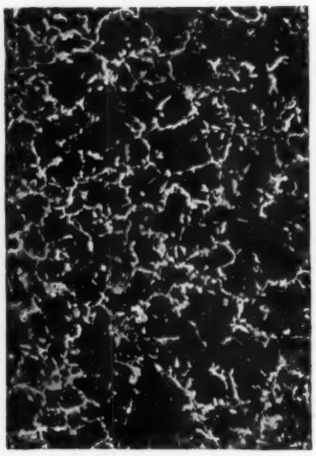

Fig. 14.—Ingot 13: Billet position 7 (top). Magnification: 50 diameters.

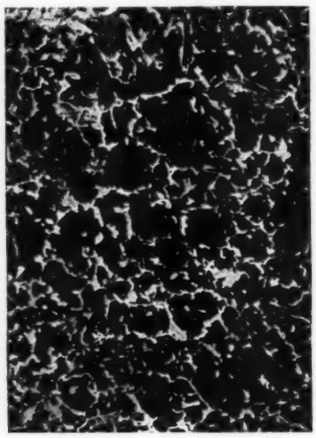

Fig. 15.—Ingot 15; Billet position 7 (top). Magnification: 50 diameters.

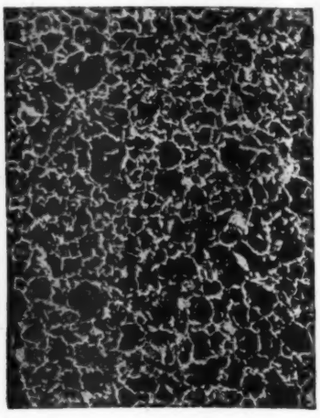

Fig. 16.—Ingot 16; Billet position 7 (top). Magnification: 50 diameters.

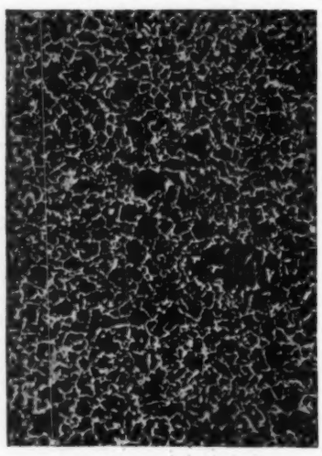

Fig. 17.—Ingot 17; Billet position 7 (top). Magnification: 50 diameters.

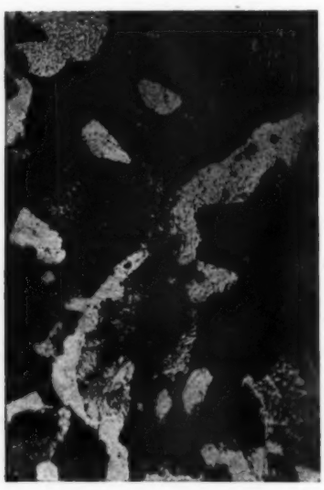

Fig. 18.—Ingot 18; Billet position 1 (bottom). Magnification: 500 diameters.

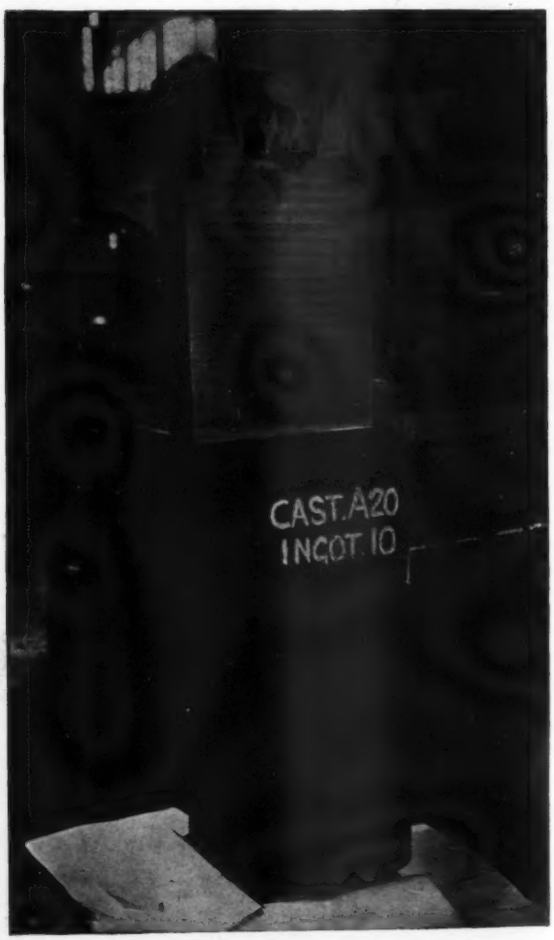

Fig. 21.—Blaenavon Shell Steel.

Fig. 19.—Ingot 10; Billet position 4 (middle). Magnification: 500 diameters.

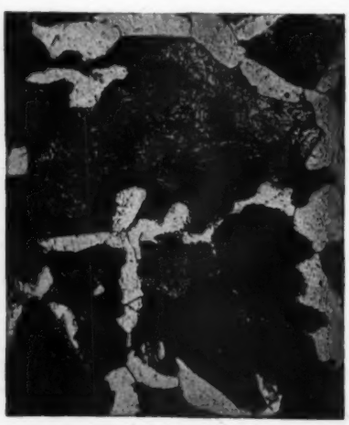

Fig. 20.—Ingot 16; Billet position 7 (top). Magnification: 500 diameters.

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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

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With Two One-Page Plates of the ARRANGEMENT OF MACHINE SHOPS, and Two One-Page Plates of the INVESTIGATION UPON A CAST OF ACID OPEN-HEARTH STEEL.

NOTICES OF MEETINGS.

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—Wednesday, October 10, at 8 p.m., at the Royal Society of Arts, John Street, Adelphi, when Lieut.-Colonel R. K. Bagnall-Wild will deliver his Presidential Address.
THE INSTITUTION OF LOCOMOTIVE ENGINEERS, LONDON, INCORPORATED.—Thursday, October 11, at 7 p.m., at Caxton Hall, Westminster. "Standard Locomotives for British Railways." Mr. J. F. Gavins, Member.
THE OPTICAL SOCIETY.—Thursday, October 11, at 8 p.m., in the Physics Lecture Theatre of the Imperial College of Science and Technology, Imperial Institute Road, South Kensington (opposite Imperial Institute). A paper on "The Grading of Carborundum for Optical Purposes," by Mr. James W. French, B.Sc., will be read and discussed. The lecture on "Polish," delivered before the Royal Institute by the Right Hon. Lord Rayleigh, O.M., F.R.S., revised by him, will be open to discussion.
THE MANCHESTER ASSOCIATION OF ENGINEERS.—Saturday, October 13, at 6.30 o'clock, at the Grand Hotel, Manchester. The business will be:—(1) Presentation of the "Constantine" Gold Medal to Mr. H. H. Asbridge, M.I.Mech.E., Member, for his paper read during the last session, entitled "Workshop Precision Grinding." (2) Inaugural Address by the President, Mr. Joseph Phillips Bedson, M.Inst.C.E., M.I.Mech.E.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal from 6d. to 8d. per copy. This increase dated from and included the issue of Friday, March 16. The change will not apply to unexpired subscriptions.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, OCTOBER 5, 1917.

PROPOSED NATIONAL SHIPBUILDING YARDS.

WE learn that there is under consideration a proposal to organise by the State entirely new shipbuilding yards. The proposition emanates from the Department of the Deputy Controller of Auxiliary Shibuilding, which includes also the supervision of the construction of standard merchant ships. Before this proposal is even seriously considered it is of the utmost importance that a protest should be entered. The question is approached here entirely from the national point of view, and not in the interests of any class. On the contrary, the shipbuilders and marine engineers in this country—and in this term we include employees as well as employers—have shown a patriotism beyond all praise. They have worked with a singleness of purpose to meet all demands, not only in respect of warships, but of merchant ships, of new work, and of repairs. So that it is futile to plead that the protest which must be entered is dictated by self-interest. Neither on the score of industrial economics nor of expediency can the proposal now under consideration be commended.

We may consider first the probable arguments in support of the institution of national shipbuilding yards. There is no doubt that the first of these is the success of the national projectile factories and, to a less extent, of the aircraft factories, but the conditions applicable to shipbuilding and the production of war material are not *per se* analogous. Before the war the facilities for the production of material for land warfare were practically negligible. It is true that the great armament firms had small departments, well organised and admirably equipped, for such work, supported principally—let it be said to our discredit—by foreign governments. When the war broke out these departments, inadequate for the enormous demands for maintaining our forces across the seas, were yet able, by the excellence of the *personnel*, to supply the nucleus for establishments which were rapidly organised. Indeed time is now only disclosing the important fact that, were it not for the members of the staff of such firms, who were commandeered to organise the national projectile factories, the state of affairs would have been serious, at the crucial moment, to land operations. The same applies to a more or less extent in connection with shell-filling, and with all appertaining to the corresponding munitions of war. As regards aeroplane constructional work, there can be no doubt that the Government made a serious mistake, and we fear are still pursuing the same unfortunate ways, in not realising that the skill and resource of private firms are of immense value, not only in securing the best designs and the most rapid methods of construction, but in that co-ordination of effort which is most essential at present.

The shipbuilding industry is on an entirely different plane. Britain was supreme in this trade, not only as regards the design and construction of warships, but also in the excellence of merchant liners and in the economy of cargo ships. We had immense resources, excelling those of all other countries in the world combined, and we led the way not only in rapidity of construction, but also in respect of economy in first cost and economy in working expenses. These shipbuilding resources in the initial stages of the war were utilised by the Government, to the exclusion of merchant shipbuilding, for the purpose of maintaining our fighting fleet and all the auxiliary ships which the evolution of naval tactics showed to be necessary. The time has come when it is realised that, in addition to the maintenance of this naval fleet and its auxiliaries, effort should be devoted to as great an extent as possible to the merchant ship construction in order to defeat the submarine menace. The shipbuilders in the country, first through a representative committee, established the lines on which standard ships should be built. They organised their works in order to co-ordinate effort to secure extreme rapidity in the completion of these ships, and to-day it is gratifying to know that this collective effort offers some surety that the losses through submarine attack, quite apart from the fact that these are steadily decreasing, will be nullified by the work done so energetically and disinterestedly by the shipbuilding employers and workers.

It is pertinent, therefore, to ask what gain can accrue by the institution of national shipbuilding yards? We have said that neither from the point of view of expediency nor economics is such a procedure justified. Let us consider the question first from the point of view of expediency. It is not prudent to indicate the extent to which merchant shipping is progressing in this country, but no harm can be done in saying that, so far as the resources at the disposal of shipbuilders and marine engineers are utilisable, much more could not be achieved. It is also permissible to say, because it is an obvious fact, that the main reason why more is not being done is because of the deficiency in the supplies of material and of labour. If national shipbuilding yards are instituted, obviously these must come under the same disabilities; indeed, it stands to reason that if men and material are available they can be more effectively utilised in existing yards, because no one can controvert the statement that there is need for more material and for more labour in such yards. Again, time must elapse before new yards can utilise material and labour, because the machine shops, construction of berths, and all the other preparations from the point of view of material, require time, and time in this case is the most essential consideration. Staffs would require to be organised for these national yards, and apart altogether from the fact that already, owing to the military demands, the staffs in existing works are at the minimum strength, it is unquestionable that in instituting new works a considerable period must elapse before individual members of a staff can settle down to that correlation which is one of the most important elements to the efficient organising of any manufacturing department, including shipbuilding. Even were there an immediate adequate increase in the material available, and an augmentation of the labour supply by more extensive dilution of labour, it stands to reason that this additional man-power, whether provided by more women workers or by German prisoners being commandeered, would be more effectively utilised by existing managers, foremen and skilled

workers, since these could augment their effort, than were entirely new staffs organised.

From the economic point of view the proposal to establish national shipbuilding yards is no less indefensible. Even if we take the long view, that after the war immense demands will be made on the shipbuilding resources of the country, it is almost axiomatic that the addition of two or three shipbuilding berths in an existing yard does not require a very material increase to the existing staff or plant. Indeed, the whole future industry demands a speeding-up as well as a replacement of obsolete machines by more effective appliances. Consequently the existing yards, with their immense experience behind them, are better able to reorganise their mechanical equipment to achieve this end than would be the case in a national factory. There is, moreover, the unanswerable economic condition that servants of the State can never work with the same desire for advancement, and therefore the same keen interest in economic success, as will employers themselves and those directly remunerated as the result of the employment of resource, experience and skill. All experience goes to prove that the servants of the State are concerned with the maintenance of tradition. They refrain from accepting responsibility, realising that failure in experiment involves condemnation and success little or no direct immediate recognition. It is true that the exceptional conditions at present prevailing, due to the war, have drawn into the service of the State, for purely patriotic motives, a large number of the best shipbuilders and marine engineers. They have done splendid service, as is proved not only by the excellence of design of war and auxiliary ships, including standard merchantmen, but in securing a high degree of rapidity in construction. It cannot be presumed that after the war these men will continue in Government service. Consequently, it must be accepted that were national shipbuilding yards at present organised by the Department of the Deputy Controller of Auxiliary Shipbuilding, these establishments would, at the termination of the war, if not before that, be deprived of the guidance which at present is the main element in the achievement of success.

Thus, from every point of view, the proposal made is a serious step which must be reviewed, not only in respect of present requirements, but of future possibilities, and in this latter consideration there is the further material point that national shipbuilding yards after the war must enter into competition with privately-owned yards for the construction of ships to be engaged not only in British trade, but even in trade between foreign countries, unless—and this is an idea which is beyond comprehension at the moment—it is contemplated to create a national shipping fleet. Whatever views may be held regarding the broad subject of nationalisation, these cannot be applied to maritime commerce, for the simple reason that it involves questions of international polity, too far-reaching to come within the compass of even the most progressive of socialistic thought.

THE PRODUCTION OF AERO-ENGINES.

The damage that is being caused by air raids on the civilians of this country is probably more than offset by the keener edge that such raids are giving to the enthusiasm and determination of all classes, notably among those who are making munitions. But they have intensified acutely the general anxiety for increased striking power in the air, or at the least for an explicit assurance that the resources of the country are being used fully and efficiently to provide it.

The Government cannot properly be asked to give the details of its building programme for increasing our strength in aircraft, nor the rate at which that programme is being carried out. But it can at least, if the facts allow it to do so, give an assurance that the best use is really being made of all available resources, and that the programme in hand complies to the utmost possible extent with military requirements. If such a statement could be made, it would give those citizens who are also engineers a confidence that they may not feel at present on certain essential points in the production of aero-engines. There is perhaps not the same anxiety in regard to the production of the planes themselves. The labour, and to a large extent the material, used in these structures is closely similar to those used by trades which for the time being are more or less in abeyance—the building and other wood-working trades, and manufactures such as those of furniture, pianos and other musical instruments, games, and the like. But the production of engines and their accessories demands labour and material of the same class as is used in other munitions industries, most of which are themselves working at or very close to their full capacity; and a production that is so placed can only be increased to its full extent if its labour resources and its material are used with the utmost efficiency.

A condition of attaining a specified production, such as is required by a definite building programme, is that the necessary labour should be forthcoming as fast as it is wanted. When labour is scarce, it is obviously no less important that the most efficient use should be made of what is available. The present aero-engine industry, perhaps even more than the manufacture of shell, has had to be improvised within the last three years. At the outbreak of war it was considered a tool-room job, to be done by men of high all-round mechanical skill. Like the manufacture of shell, it has reached its present dimensions partly by subdividing the work as far as possible, so as to separate what requires skill from what, on a suitable machine, can be done without it; and partly by training women to do one or other of the accurate operations, which previously had been left to men who could do them all. As we have repeatedly pointed out, it seems as though in some industries women were not being fully employed on all work that they can do. In commenting, for example, last week on the admirable Exhibition of Women's Work that the Ministry of Munitions is now giving at Sheffield, we had occasion to remark that in the manufacture of aero-engines women appear to be prohibited in some works from doing operations which they are doing successfully in others, and the work is thus added to what has necessarily to be done by skilled men, of which the limited supply puts a limit on any production which is dependent on them.

Another condition for efficient production in large quantities is suitable and standard design. In normal conditions of trade the design of a complex mechanism such as an engine need not be standard throughout a whole trade, as details such as screws and bolts should be. The cost of manufacture of a given design is reduced but little by increased production after a certain output has been passed; and probably an industry may be more progressive, and a works in competition with others may be better able to build up a stable business, if the firms whose production is large enough to be economical retain individual differences of design, by which their own goods may be identified and pushed, and the experience of users may be widened. It may, moreover, be to the advantage of works that are already established in an industry to favour designs and methods that make and keep their products dependent on exceptional skill, and so limit the number of their possible competitors. But whether these are or are not normal and proper working conditions for competing firms in an industry regulated by economic laws, they would directly reduce the collective output of firms who are co-operating for a national purpose, and for the time being must regard economic laws as of secondary importance.

It is no reproach to the aero-engine industry that its present condition should suggest these reflections. In the forcing-house of the war industries have had to produce in a couple of years a development that in ordinary times would have done credit to a generation. The development of British aircraft design and manufacture is among the most striking examples of such rapid growth; and possibly, in the early stages of the war, when immediate production was indispensable, although the experience necessary for assured wholesale decisions had not been acquired, it may have been desirable to allow a large measure of latitude to firms to develop along their several lines, so as to give those who had to use their products a wider and quicker opportunity of forming their judgment. To some extent, no doubt, the different purposes for which aeroplanes, including sea-planes, were required demanded differences in design. These essential purposes, however, are not numerous. When types are constructed suitable for teaching, practising, signalling, reconnoitring, fighting and bombing, probably most of the necessary provision has been made; and apart from increasing needs for power, which with a suitable design might well be met by combining standard units if they were designed with this contingency in view, the number of separate types of engine that are necessary for equipping such planes must be much smaller even than the indispensable variety of the planes themselves.

Yet it is no exaggeration to say that the types of aero-engines on the market—and for the present there is no market but the military services—run into dozens. If these were all equally suitable and efficient in use, equally easy and rapid in manufacture, each separate type would still increase the stock of spare engines and spare parts that would be required for reserve, and to the same extent reduce the output of engines for the equipment of fresh machines; while differences in manufacture would increase the difficulty of transferring fresh labour that had been trained on one operation to works in which some other operation was substituted. On the scale on which aeroplanes are required these disadvantages would in themselves be grave objections to continuing the production of a greater variety of types than is indispensable. But it is difficult to believe that all types can be equally efficient and equally easy and rapid in manufacture; and by whatever percentage one type takes longer or is more difficult to make than another, by the same percentage the output of engined aeroplanes is reduced.

The anxiety of engineers who are familiar with problems of manufacture but are not acquainted with the present arrangements for producing aero-engines lies in the doubt whether those arrangements are complying with the essential conditions of maximum production to which attention is here drawn. The importance of having this doubt resolved appears to us so great that we express it in three direct questions:—

1. Is labour of the required skill being actually recruited at a sufficient rate to provide engines punctually to the dates required by the present building programme for aircraft?

2. Have all restrictions on the employment of women been now withdrawn, and is a sufficient force of them being trained to meet whatever part they have to undertake in producing the required engines?

3. Have the designs of aero-engines been so standardised as, in the opinion of engineers with practical experience of the intensive manufacture of machines in series, to reduce the number of separate designs to the minimum that will serve the several purposes required?

We put these questions plainly because, even if a satisfactory answer cannot as yet be given, there is nothing to prevent a candid admission of the fact from being accompanied by the reassuring announcement of further arrangements for doing what is required. The facts that are known to engineers do not compel the conclusion that even the present answers must be unsatisfactory; but they do suggest that they may be. What alone engineers know for certain is that, if the building programme represents the needs of the services, these needs cannot be satisfied till these questions are answered affirmatively.

FERRO-CONCRETE SHIPBUILDING.

Interest in ferro-concrete ships is greatly increasing, and it is satisfactory to learn that the Committee of Lloyd's Register of Shipping have approved plans for the construction of a number of such ships up to 500 tons deadweight capacity, after careful consideration and in the light thrown on the subject by the report of one of their surveyors upon a visit to works in Scandinavia, where, owing to exceptional circumstances due to the war, more

work has been done in this new departure than in other countries. The attitude of Lloyd's is an important commendation of the principle, as the supervision of building operations for classification in their register, carrying as it does ensurance of underwriting, is certain to encourage the use of ferro-concrete as a constructional constituent for certain types of craft. Recognition of limitations and the influence of war conditions is justified, although the Committee of Lloyd's Register are not likely to enunciate any definite views. At the same time it is interesting to have the views of the organisation in Norway which is somewhat analogous to Lloyds, since opinion in that country is supported by a certain measure of practical experience, if influenced also by the absence of metals for shipbuilding and the need of rehabilitating the shipping fleet severely depleted by war losses.

A director of the Norwegian Veritas has lately given his views on the subject, unofficially. He was convinced, he said, that ferro-concrete, under normal conditions, would be used for lighters, floating docks, buoys and other floating objects where the weight did not play a very important part. As far as seagoing vessels were concerned, he was of opinion that the weight of ferro-concrete vessels would detract from their carrying capacity to such an extent that it would be difficult for them to compete against vessels built of steel in normal times. On the other hand they possessed a great momentary interest, as they offered a possibility of procuring some tonnage to make up for all the vessels that had been lost. He pointed out that more experience was necessary, and referred to a lengthy communication on the subject he—some weeks ago—had forwarded to the chairman of the Norwegian Veritas. In this he underlined the material difference between using ferro-concrete for lighters, as had been done in Italy for several years, and for seagoing vessels.

Experience from ferro-concrete constructions on shore is not directly applicable to vessels. Fixed structures, as a rule, are only subjected to a load the maximum of which is known, and which only acts in one direction, whereas the load to which a vessel may be exposed cannot be directly calculated, and its direction is constantly varying, especially in a turbulent sea. Under these circumstances, pending fresh experience, the strength of a ferro-concrete vessel must be determined by comparison with that of a steel vessel of the same type and dimensions. This, however, is a difficult problem, as a steel vessel, on account of peculiarities in its construction and building, in some directions may have more material than necessary from general strength considerations, and also because several qualities of concrete, which it is necessary to know in order to make fairly reliable comparisons with steel vessels, are not yet sufficiently ascertained. The actual building process of a ferro-concrete vessel is such that the quality of the material and the workmanship cannot be controlled with the certainty obtaining for steel vessels.

In connection with the strength of reinforced concrete it must be remembered that the tensile strength of concrete is very limited. Tensile stresses must, therefore, be carried, as far as possible, by the reinforcing steel. In a floating structure, however, the concrete cannot be altogether guarded from tensile stresses, which are apt to create small cracks. Such cracks may also arise during the setting of the concrete. On shore they are generally considered to be of minor importance, but it is by no means certain that such cracks may not play a different part in vessels exposed to varying stresses and the effect of penetrating salt water.

As to the watertightness of cement, apart from cracks, this can probably be attained by using sufficient cement, by mixing certain chemical substances with the concrete, or by giving the vessel a waterproof coating. The life of a ferro-concrete vessel will no doubt to a great extent depend upon the chemical composition and watertightness of the concrete, on the proper placing of the reinforcement at a sufficient distance from the outside of the concrete, and on the effect of salt water upon concrete and upon the reinforcement if there be cracks. Judging by experience gained from ferro-concrete quays, it may perhaps be assumed that the durability, when the necessary precautions are observed, will be satisfactory, but experience can alone settle this question. It will also be of interest to learn what effect waste oil in the motor-room will have, as oil is generally supposed to affect the strength of concrete in an unfavourable manner. In conclusion it must be remembered that the strength of concrete increases materially during the first months after mixing.

It is certain that a large number of ferro-concrete vessels will be built in Norway in addition to those already built, and therefore the classification societies will be obliged to take some action. It has therefore been suggested to the Norwegian Veritas that they should open a classification for ferro-concrete vessels, subject to certain precautions, as, for instance, a limitation of the waters to be navigated, and subject to the class in the register being defined as experimental.

At present it would be inadvisable to fix rules for the building of such vessels, and it should be left to the director to judge each case individually on its merits, until it can be ascertained how the methods of construction and building of such vessels are developing.

Meanwhile conditions favour the building of ferro-concrete ships in Norway, as elsewhere. The times are not normal; freights are very high, and it will be long before they fall to pre-war figures, and any vessel that will float and carry cargo may be relied upon to earn large profits. Steel plates and angles are difficult to obtain, while cement can scarcely find a market, and concrete aggregate is abundant. Ferro-concrete, with its moderate demands for steel, and that in the simplest form, therefore has attractions which have led to serious attempts to employ it in shipbuilding. Already encouraging results have been attained. On August 1 there took place the trial trip of the Norwegian vessel Namsenfjord, with entirely satisfactory results. She is 84 ft. long, 20 ft. broad and 11.6 ft. deep. The hull is monolithic with the deck and the frames round the hatches and those serving as foundation for the cabin aft. Outside the hull are two large wooden fenders. The vessel is admirably suited for the transport of timber, and is fitted with appliances for prompt loading and discharging and with a Bolinder motor. The vessel will be put on a Norwegian coasting route.

The Fougner yard has already commenced work on its eighteenth ferro-concrete floating structure, a floating dock, while several vessels up to 1,000 tons deadweight have been contracted for, besides a lightship for the Ildjern Shallow. A vessel ordered by the South Varanger Iron Ore Company will have double sides and bulkhead, being intended for the transport of ore, which does not take up much space. Sister companies of the Fougner Ferro-concrete Shipbuilding Company are in the course of formation in England and America. Provided the necessary raw materials can be obtained, the Norwegian yard can build some 30,000 tons a year.

The same day as the Mamsenfjord was launched from the Moss yard the first ferro-concrete lighter, Beton I, was launched from the Porsgrund Cement Works. The launch was particularly interesting from the manner in which it took place, inasmuch as the lighter was sent into the water bottom upwards. This was done in accordance with calculations undertaken by the director of the company, and these were entirely borne out by the way in which the lighter, in less than twenty minutes, righted itself, floating on its keel in the usual manner. The lighter has a capacity of 200 tons deadweight and is to have a 70-h.p. Skandia motor installed. As this vessel was constructed by the firm which built what is claimed to have been the first ferro-concrete vessel in Norway, and has in its experimental and practical work acquired great experience—the Porsgrund Cement Casting Company—the illustrations we give of the Beton I in this issue will be studied with special interest.

Preparatory work was taken in hand by them in 1913, and an engineering firm was commissioned to undertake the necessary calculations. Designs were prepared for lighters of different types and sizes, but building work was not proceeded with at the time, the company being very fully employed otherwise. In 1915 a bridge pontoon of reinforced concrete was built for the Porsgrund municipality after the design of the same engineers. The pontoon was of the following dimensions: length, 16 m. (52 ft. 6 in.); breadth, 5 m. (16 ft. 4.8 in.); and height, 2 m. (6 ft. 6.7 in.). It had a deck fore and aft and two watertight bulkheads. The casting was done with double boarding in the walls. The bottom and sides, with ribs and bottom girders, were cast between 6 a.m. and 10 p.m. on one day. The deck was formed during the next forenoon. Twenty men were at work, and the casting was pushed ahead as fast as possible so as to avoid any faults in the concrete. The mixture was 1 : 3, with small cobbles only in the ribs; the walls were 5 cm. (1.97 in.) thick. The pontoon was not polished, as it proved watertight without this being done. The experiences resulting from this first enterprise established the very considerable difficulties connected with double boarding. It was a troublesome task properly to arrange the reinforcement, and there was no actual guarantee that the iron would be in the right positions. The casting itself entailed a good deal of trouble, and the greatest care had to be taken to make sure that it was thoroughly well done. The most difficult points were those where sides and ribs adjoined the bottom. As a matter of fact it was found that in one or two places there were faults in the casting, which had to be remedied. The pontoon is now used, as it was originally intended to be, as a supporting pontoon, but was first employed for the transport of sand and other material, and thus it is claimed for it that it was the first ferro-concrete vessel or craft built in Norway.

Consideration of the difficulties led to the belief that they would be overcome in the case of lighters with a fairly rectangular section were great care shown, but when it came to the building of vessels of ordinary section the difficulties would be very serious. The Italian builders use network without boarding. The director of the Norwegian company, who personally had taken much interest in the work, M. Harald Alfsen, had from the outset been convinced that ferro-concrete boats should be built bottom uppermost, and by using only an inner shuttering, or only outer boarding, as far as the vertical sides were concerned. In order to do this, however, the problem of how to turn a boat of fair dimensions upright had to be solved. The solution was found last year, and consists in letting the boat take the water bottom upward, in the position in which it is cast.

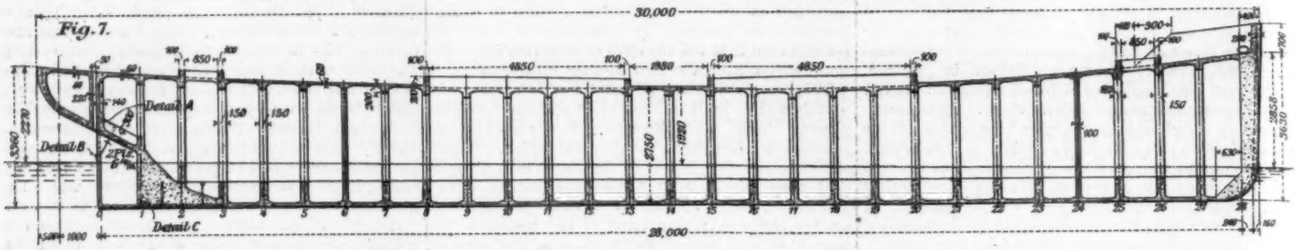
We defer, until our next article, a description of the methods adopted in uprighting the vessel after launching, contenting ourselves for the present with a description of Beton I. On page 362 we give six perspective views, two of the interior and four of the holds, showing the framing, from photographs taken after the vessel had been launched. On page 366 we give longitudinal section, plan, cross-sections and details, which clearly show the reinforcement of the concrete hull. Fig. 18, on page 367, is a perspective view showing the interior shuttering.

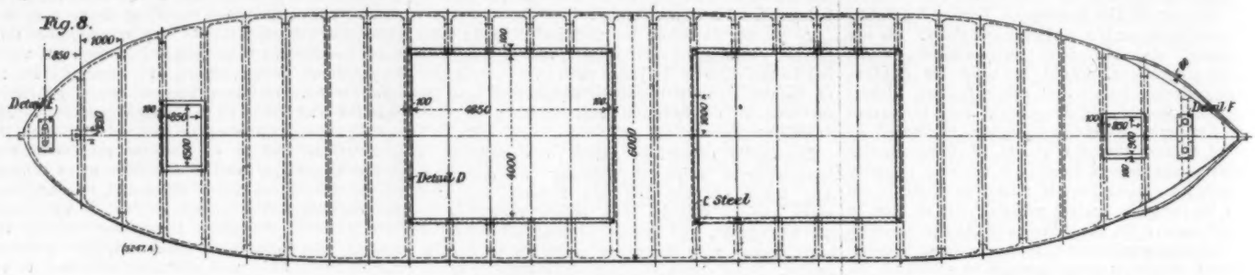
The details show what is called the Alfsen method applied to this Beton I—a 200-ton deadweight carrying motor vessel. The calculations and design were prepared by the engineers, Messrs. Bonde and Norman, already referred to, the line drawings being entrusted to a ship constructor. The general dimensions are given on the drawings. The previous calculations for the lighters and the pontoon could no longer be used, these being intended for inland waters and river traffic. For seagoing vessels altogether different stresses had to be reckoned with. As it turned out, the reinforcement for the latter had to be more than 50 per cent. heavier than for the lighters, at the same time the rib and girder dimensions had to be materially increased. A very "fat" mixture was decided upon, without any cobbles being used. The thickness of the walls was fixed at 50 cm. (1.97 in.), the depth of the ribs in the bottom at 600 cm. (23.6 in.), and in the sides at 250 cm. (9.8 in.). The thickness of the ribs is 150 cm. (5.9 in.).

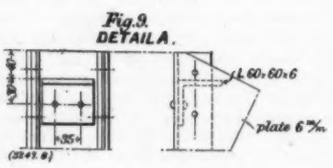
The work proceeded in the following manner. The shuttering (Fig. 18) was first put up completely on a

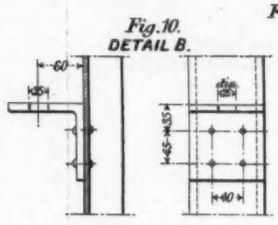
THE FERRO-CONCRETE SHIP "BETON I."

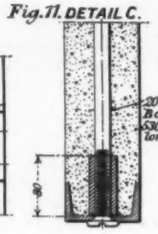
CONSTRUCTED AT THE PORSGRUND CEMENT WORKS, PORSGRUND, NORWAY.

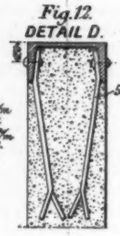


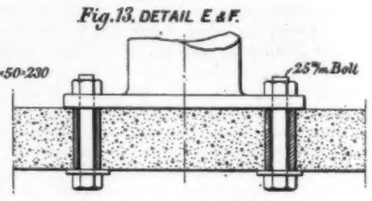


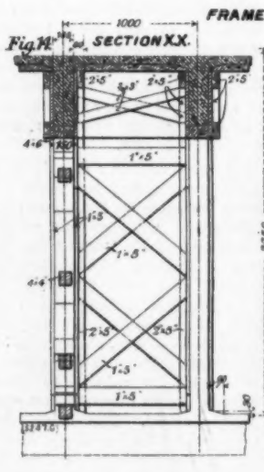


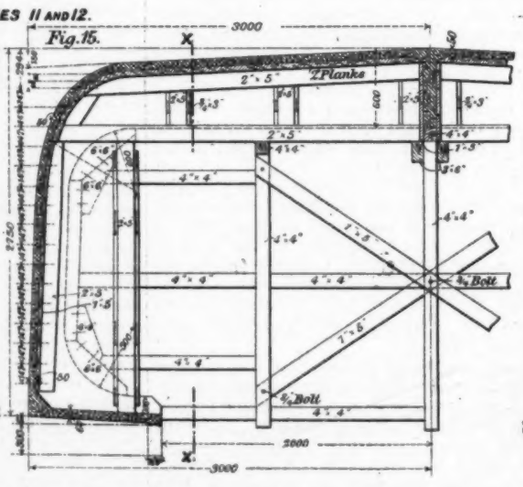


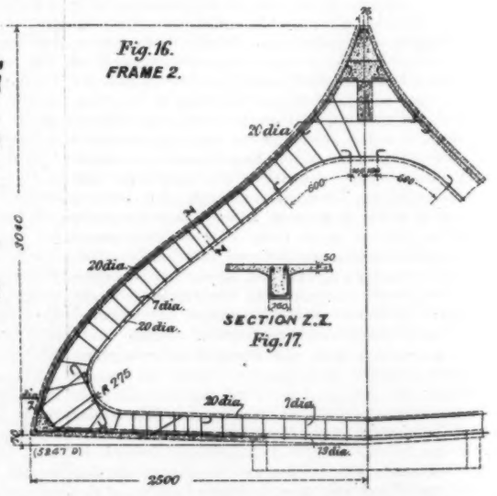












sledge, which followed the vessel into the water at the launch. The reinforcement was also arranged completely before the casting commenced. In building the first vessel the arrangement of the boarding took three weeks and that of the reinforcement an equally long time, but this work, it is confidently anticipated, can be done in half the time for the next vessel. The casting itself was got through in two days, it being commenced early Thursday morning, July 26, and the casting of the concrete was finished at 6 o'clock on the following afternoon. Any after-polish was entirely completed at noon on the Saturday. A period of three weeks was allowed for the concrete to set on account of the strong mixture (1 : 2), and it may be taken that a vessel of this size can be built every six weeks on each slip. During the greater part of the casting 60 men were employed, for a short time 55 sufficed. The concrete filling and the polish were partly done by hand and partly by compressed air appliances constructed by the company. The shuttering was made of strongly dimensioned material arranged in such a way that it was easy to detach it and put it together again for many succeeding vessels.

(To be continued.)

NOTES.

The Official Contempt for Science.

In an interesting presidential address to the Rotherham Technical Institute Engineering Society Dr. T. Baker drew attention to the extent to which we had before the war become dependent on Germany for certain supplies essential to our industries. The list included, he said, miners' lamp glasses, chemical glassware and chemicals, as well as certain important metal products. The dangers inherent to this condition of affairs had been frequently pointed out, but no impression was made on our official classes, whether permanent or political. This apathy Dr. Baker attributed largely to the classical tradition of our public schools and Government services. The contempt of the higher permanent officials for scientific acquirements was, he observed, well illustrated at the outbreak of the war, when, in advertising for highly qualified chemists, they fixed the pay at 2*l.* 0*s.* 6*d.* per week. Fortunately the advertisement did not prove as ineffective as it deserved to be, since the patriotism of most chemists stands higher than their desire for personal gain. Indeed, had this not been the case, it is difficult to see how we could have carried on. It is our scientific men who have come to the

THE FERRO-CONCRETE SHIP "BETON I."

CONSTRUCTED AT THE PORSGRUND CEMENT WORKS, PORSGRUND, NORWAY.

(*For Description, see Page* 364.)

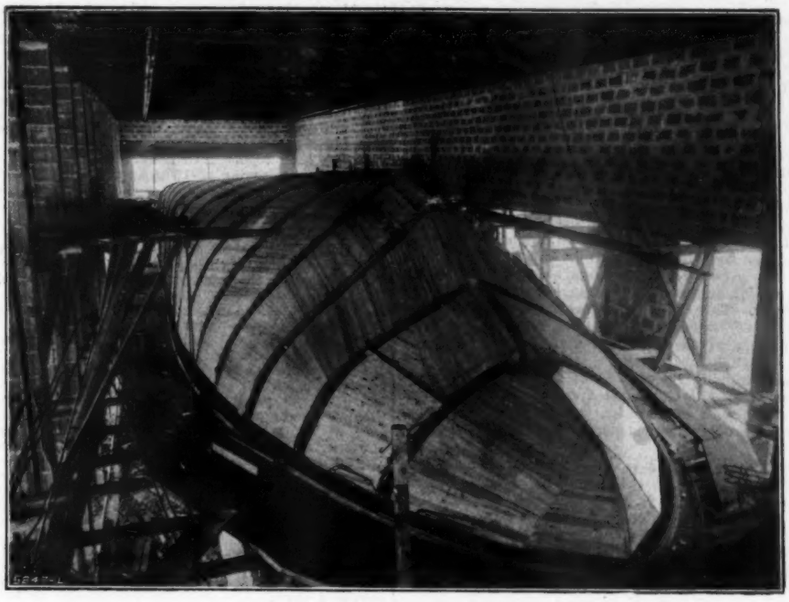


Fig. 18. Shuttering for the Interior Walls of the Hull

rescue, as Dr. Baker points out, and shown how the glasses, chemicals and drugs previously obtained from enemy Powers could be equally well manufactured here. Indeed, some of our university and college laboratories have become manufacturing establishments *pro tem.* and themselves supplied many materials otherwise unprocurable.

High-Efficiency Reciprocating Engines.

It is probable that the reciprocating steam engine has been permanently dislodged from large power stations by the steam turbine, but in the case of small plants the reciprocator seems capable of successfully holding its own so far as questions of thermodynamic efficiency are concerned. Some interesting data as to what is now practicable in this regard are to be found in a paper by Mr. S. Rosenzweig, contributed to a recent issue of the Journal of the American Society of Mechanical Engineers. The engine tested had poppet valves and was constructed on the uniflow system, which, originally suggested by Todd, owes its recent developments to Professor Stumpf. The test results were as follow :—

Steam pressure (pounds per square inch gauge)	213	432
Steam temperature (degrees F.)...	923	1,018
Indicated horse-power	112	99
Revolutions per minute	150	158
Vacuum, inches of mercury ...	27.7	26.7
Steam consumption per indicated horse-power (pounds)	6.53	5.68
Heat consumption per indicated horse-power hour (B.Th.U.) ...	9,720	8,640

It is of some interest to note that the efficiency ratio in the high-pressure trial was about 87 per cent., reckoned on the indicated horse-power and on stop-valve conditions. This figure could certainly not be approached with a steam turbine of anything like so small a size, although some able engineers consider that with large sizes of steam turbine the development of a brake horse-power for an expenditure of 8,000 British thermal units per hour is within the range of possibility. In his article Mr. Rosenzweig gives some interesting comparative figures for Corliss valves and poppet valves providing equal steamway. Corliss valves giving a free area of 65 sq. in. were found to weigh 824 lb., whilst the weight of four poppet valves also giving a free admission area of 65 sq. in. was but 72 lb. The introduction of the poppet valve for steam engines he attributes to the late Charles Brown. They have, he states, the advantage of avoiding rubbing surfaces, and thus require no lubrication, and they can be used both with high pressures and high temperatures. The wear is insignificant, the valves remaining tight for long periods, and their light weight makes higher running speeds possible than would be practicable with Corliss engines. Trip gears should, he holds, not be used for poppet valves, but they should be opened and closed positively, thus avoiding the hammering between seat and valve, unavoidable where a trip gear is used.

Tapping Lake Ritom.

The provision of electric power for the Gotthard Railway by the Swiss Federal Railways, to which we referred on page 185 of our issue of August 25, 1916, involved the tapping of Lake Ritom, in the Canton of Tessin, at a depth of 30 m. below water-level. The sloping lake bottom was to be approached by a horizontal tunnel from the south, 220 m. in length; sluices were to be fixed in this tunnel, and their operation and the general exigencies of the work necessitated the sinking of a vertical shaft, 35 m. deep, from the bank of the lake down to the bottom of the tunnel, which it was to strike about 98 m. from the spot at which the lake bottom was actually to be pierced. The tunnel was thus divided into two sections, the tapping conduit proper, extending from the lake about 98 m. to the shaft bottom, and the discharge conduit, about 122 m. in length, from the shaft to the Fossbach, which now carries off the lake water. The tapping—the most dangerous part of the whole scheme—was successfully carried through last February. The hard rock, mainly mica schists and gneiss, inclined about 50 deg. to the horizontal, facilitated the work. By extensive soundings it had been ascertained that the lake bottom at the spot in question consisted of hard rock covered by mud and detritus. The blasting of the tapping conduit advanced at the rate of about 2 m. (2.5 m. maximum) per day for the first 85 m. from the shaft. Operations then proceeded more cautiously. At 94 m. special borings disclosed a fissure carrying water and mud; the water was, moreover, charged with sulphuretted hydrogen, which was known to be present in the lake water, and this gas, escaping also from other spots, troubled the men a good deal. It was therefore resolved to impregnate the rock wall in front with cement under a pressure of 3.5 atmospheres. The tunnel, now only 1.6 m. square in section, had already been deflected upward so as to meet the dip of the rock at right angles. Through a small boring right ahead mud and water were afterwards forced in when a depth of 3 m. was reached. Advance was now made by blasting holes not more than 0.5 m. deep, until four new borings showed that the rock wall left had a thickness ranging from 1.35 m. to 1.75 m. It was decided to break through this thickness by one final blasting. The four holes just mentioned, and 13 more, leaving only 30 cm. of solid rock between tunnel and lake, were charged with blasting gelatine and then tamped with cement. A special gelatine had been ordered; but it was frozen hard—the temperature was —18 deg. C. (about 0 deg. F.)—and had to be thawed. The total charge of 68 kg. of gelatine and 100 explosive capsules was put in the holes between 11 a.m. and 6.30 p.m. on February 3, 1917, by Messrs. C. Lucchini and Trepp. The firing, from the top of the shaft, by means of fuses and electric leads, took place on the same evening. The explosion was instantaneous; within 10 seconds water sprayed out of the shaft and rushed through the tunnel. The discharge stopped soon, however, because the detritus had blocked one of the two sluices which had been left open. By carefully opening this sluice further next morning the passage was cleared; this sluice was then closed again, while the other sluice was opened to wash out the stones blocking that passage. Thus Lake Ritom was tapped without any mishap. The occurrence of sulphuretted hydrogen in the water is peculiar. The upper 12 m. of the lake water were practically free of this gas; at that depth the water was red with some sulphur-bacterium, and nothing could live in the deeper water, which contained up to 25 milligrammes of H_2S per litre, according to Professor Mellet. Fortunately this H_2S is so readily decomposed by the oxygen of flowing water that the discharged lake water has not injured the fish in the Tessin River, which it enters.

INDUSTRIAL NOTES.

The order for the abolition of leaving certificates, which takes effect on the 15th inst., as referred to on page 341 *ante*, involves a new demand on the patriotism of all workmen engaged in the production of munitions. The leaving certificate was designed to promote continuity of employment—on essential war work—and it has limited the freedom of both employers and men. On and after the 15th inst. any workman engaged on the production of munitions will be free to leave his present employment for other war work on giving his employer a week's notice, or such notice as is provided for in his existing contract of service.

Some dislocation of work is probably inevitable; it is obvious that if the dislocation were to develop to any considerable extent, the production of munitions would, for a time at least, be seriously imperilled. The Trade Union Advisory Committee has been quick to realise this possibility, and has addressed an urgent appeal to all workmen not to change their employment unless for definite and substantial reasons. The Minister of Munitions is also taking steps to spread any inevitable change over as long a period as possible.

After consultation with representatives of both employers' and workmens' organisations Mr. Churchill has decided that in controlled establishments and certified undertakings provision should forthwith be made to grant certificates to men who are known to be desirous of leaving for other employment whenever they can be released without serious dislocation of work. Under this arrangement the cases of men who have been long absent from their homes will have special consideration.

It has been decided to extend the War Munitions Volunteer scheme. This extension will meet the difficulties of men in the engineering, shipbuilding and allied trades who are working away from their homes. All of these men who are eligible will be free to enrol as Munitions Volunteers and will become entitled to subsistence allowance. Married men and unmarried men whose homes are mainly dependent upon them will receive an allowance of 2*s.* 6*d.* per day; unmarried men whose homes are partially

dependent upon them will receive an allowance of 1*s.* 6*d.* per day. The Munitions Volunteers will be entitled to free railway passes to and from their homes on general holidays.

The Ministry of Munitions relies confidently on the hearty co-operation of all classes of workers, who have so long demonstrated their loyalty and their unswerving devotion to the national cause, to maintain an ample and increasing supply of the munitions which are more than ever essential to victory in the field.

The Land Union, 15, Lower Grosvenor-place, S.W. 1, has published, at the price of 1*s.* 2*d.* post free, a pamphlet dealing with "The Housing Question as affected by Recent Legislation," in which are given reasons for the repeal of Part I of the Finance (1909–10) Act, 1910. The case against the taxation and valuation under Part I. of the said Act is reviewed in detail in the pamphlet and is summarised under three main headings as follows: The legislation, it says, has had a most pernicious effect on the building industry and the development of land. The valuation carried out under the Act is of no use for any extraneous purpose. The legislation, so far from producing revenue, has caused a great loss to the State and to individual owners; it has in this respect not only been an utter failure, but by depreciating the market value of a great national asset must tend to cause a loss to the Exchequer in estate duty and other duties on transactions in land.

Speaking at the annual meeting of Messrs. John Brown and Co., Limited, on September 27, at Sheffield, Lord Aberconway said it might interest the meeting to know what the workmen of the country at large were doing. They heard of strikes and disputes—far too many of them he admitted, but there was a brighter side to it. If they took the nation as a whole, its man-power in production had increased 30 per cent. over that in normal times, though with 30 per cent. less male population. Those were, he thought, very remarkable figures, and would have been impossible but for the valuable help women were rendering. The amount of work done by women in such concerns as theirs was enormous, as an inspection of any of their works would show. With regard to coal, the country was producing within 10 per cent. of its pre-war standard, although tens of thousands of miners had gone to the front. Although it was regrettable that in many cases miners were not working all the time that might be expected, still the output per man in the collieries was greater to-day than it was before the war. With regard to pig-iron, in spite of the depletion of men, the output was normal, and with regard to steel they were turning out 20 per cent. more than the pre-war standard. Those were very encouraging figures from the point of view of the future development of the country, and when it was remembered that chemists and technical experts were making the country independent of foreigners in all metallurgical operations, in alloys, glassware, dyes and electrical apparatus, they might feel that the war was doing a very good thing in many directions.

The Prime Minister, he added, recently said a good deal about present and prospective achievements in shipbuilding. He (the speaker) wished he could give the real facts and figures, and he could not see why the Government could not do so. It would not be wise to reveal what was being done at present, but there could surely be no harm in saying what had been done, and it would certainly not tend to the encouragement of the enemy. John Brown and Co. were preparing for a very large steel and shipbuilding output in the future. They had doubled and trebled their capacity of output so far as shipyards were concerned, and he was quite certain that that would be almost the dominant trade in years to come. The shareholders would reap the benefit of this expenditure after the war.

Sir Arthur Steel-Maitland, M.P., presided at a meeting held last Monday at Queen's College, Birmingham, under the auspices of the National Union of Women Workers. In the course of his speech he stated that with so many men diverted to fighting and to other purposes, the need for women workers had been increased manifold, and instead of there being a glut of women workers, there was now a great demand for them. It had been found from the experience of the war that women had been able to do work which formerly was reserved for men. Not only so, but the substitution of new kinds of machinery for old in many of the engineering works had enabled a certain amount of work to be done by women with the new machines which probably could only have been done by men on the old machines. The result was that after the war the problem would be quite different from what it was before. For that reason, he thought the subject was well worth considering now, so that they might have a better knowledge of where they stood in regard to the matter. After the war there was bound to be a good deal of dislocation in the country, inasmuch as when the men returned some industries would stop and others would be starting work again. The amount of dislocation and hardship that would be entailed would depend a great deal on the measures taken to meet it, and on the understanding and intelligence of the people generally who would be affected or who could influence the people who were affected. He believed that if there was goodwill not only could the production of this country be immensely increased as compared with what it was before the war, but the situation of the people who were underpaid before could be made as it ought to be made, a great deal better.

Mr. Edward Porritt, an author of wide British and American experience, writing from Hartford, Conn., U.S.A., to *The Glasgow Herald*, says that the only direct interference by the United States Government with labour has been in the shipbuilding industry. There has been no attempt to fix wages. Interference has been so far by agreement, and solely for the purpose of avoiding or quickly adjusting, labour disputes in the industry. The plan to this end was adopted on August 25, when representatives of all the Labour unions signed an agreement with representatives of the United States Navy Department, of the United States Shipping Board, and of the Emergency Fleet Corporation—all Government organisations that are concerned with construction work now in hand either for the war, Navy, or the merchant and Army transport services.

Mr. Porritt further states that disputes were delaying work at shipyards in the vicinity of New York, and in at least one yard on the Pacific Coast, at the time the agreement was signed. These disputes had not been completely settled a few weeks ago. But the new agreement carries at least a promise of fewer disputes in these times of unprecedented pressure on American shipyards, and of almost bewildering activity in the organisation of new shipbuilding companies and the installation of new shipbuilding plants. It has given great satisfaction to Mr. Gompers and his associates in the leadership of the American Federation of Labour, chiefly because of the full and complete recognition of the Labour unions that is embodied in it. Mr. Gompers is sure that it will inspire confidence in the ranks of organised shipyard labour because it is based upon standards of wages and conditions of work that are in accord with fair dealing. "The agreement," Mr. Gompers added, "indicates a desire of the Government and of organised Labour to deal with labour problems with a spirit of fairness. Its conformity in principle with the understanding of June 19 between Secretary Baker and myself to adjust Labour difficulties developing in cantonment construction augurs much for its effectiveness. This plan was later extended to cover aviation work, repairs, and all land construction for both Army and Navy."

The Minister of Reconstruction has appointed a committee to advise him as to the procedure which should be adopted for dealing with the position of the chemical trades after the war.

The officers of Government Departments who form part of the committee are appointed with the concurrence of their respective Ministers, and the other members of the committee have been appointed at the suggestion of a representative meeting of chemical manufacturers.

Dr. Addison has requested the committee to conduct their deliberations with a view to the creation of some organisation which should be adequately representative of the trade as a whole, and by means of which the trade may be enabled hereafter to continue to develop its own resources and to enlist the closest co-operation of all those engaged in the chemical industry.

Association of Engineering and Shipbuilding Draughtsmen; Merseyside Branch.—The annual meeting of the members of this branch was held at Birkenhead on Saturday, September 29, under the chairmanship of the president, Mr. J. D. Murray. Reports were presented by Mr. A. Halsall, branch secretary, dealing with the progress and operations of the association as a whole, as well as of the Merseyside Branch, the membership of which was shown to have increased by about 50 per cent. during the year. The present membership was shown to include representatives from nearly all the engineering and shipbuilding firms, and from the principal shipping companies in the neighbourhood. A satisfactory financial report was presented by Mr. D. Spencer, the treasurer for the branch. Various matters were discussed bearing upon the work and position of draughtsmen, and it is hoped that arrangements may be made, as in other centres, for meetings which will contribute to spread information and to increase the efficiency of the members.

FUEL ECONOMY IN BRASS-MELTING FURNACES.

To the Editor of Engineering.

Sir,—In Mr. Harvey's paper on "Fuel Economy in Brass-Melting Furnaces," read at the Institute of Metals last week, the basis of the author's remarks appears to lead to rather a prescribed view of the question of fuel economy as affected by the different systems of heating metal-melting furnaces, and I should like both to add somewhat to his remarks and to extend his method of analysis in the case of three of the systems.

Powdered Coal.—According to the author, this particular type of appliance is capable of giving the highest overall fuel efficiency, the thermal efficiency of the furnace being 15 per cent. It is generally conceded that powdered coal as a fuel is only practicable for large installations, as it would probably not pay to put in a coal-milling plant for the small amount of fuel used in the ordinary brass foundry.

It has been reported that by the adoption of this form of fuel a saving of 15 per cent. to 20 per cent. would obtain as against that used in the direct firing by means of coal in a reverberatory furnace. Hitherto certain troubles have been incorporated with this system of firing, due to the clogging of flues with ash and the fluxing action of this ash on the refractory linings, a trouble which is to be anticipated in crucible furnaces fired in the same manner, and which would be very liable to cause a marked erosion of the pots. It is conceded that the fuel can be burnt through a nozzle or burner in a manner very similar to gaseous fuel, and that a certain amount of control of the atmosphere in the furnace can be obtained without much difficulty. The use of powdered coal would also appear to have advantages which would commend it for open flame furnaces owing to the possibility of utilising low-grade fuels, which it might not be possible to employ successfully even in a gas producer. Mr. Harvey does not refer, however, to these possible advantages, but appears to demand a constant quality of coal for all the types of furnace which he discusses. He appears to make no allowance in his summary for the fuel consumption necessary for the preparation of the coal, nor is he in his review concerned at all with the question of additional charges for labour in handling, storage, ash removal, &c., in connection with solid fuels. In the early part of his paper he mentions that the loss in the producer system counter balances the energy required to grind coal to the powdered state. The producer loss he puts at 10 per cent. A similar allowance, then, for the preparation of the fuel would reduce his overall efficiency to 13½ per cent. Thus from the coal there is obtained by this system about one-seventh of the total available energy, and there are no by-products with which to credit the system.

Town Gas Fuel.—An arithmetical error has, I think, crept into this estimation; the figure for total gas burnt should read 14,173,000,000 cub. ft., instead of 14,336,000,000 cub. ft. This being so, the Harvey ratio in that case becomes 1 to 28.3, and on making allowances for the coke obtained at the gas works the ratio becomes 1 to 11.3.

If, on the other hand, a balance-sheet is drawn up showing the yield from each ton of coal carbonised, the position of town gas is found to be much more favourable than indicated by Mr. Harvey.

For every ton of coal put into the retort there is obtained, after deducting the coke necessary for the heating of the settings, 11 cwt. of gas coke, 16 gallons of tar, 35 lb. of ammonia sulphate, 4.5 lb. of sodium ferrocyanide, together with 12,000 cub. ft. of coal gas. Deducting 10 per cent. from this latter figure for leakage in transmission, there is then available 10,800 cub. ft. of gas. For the sake of comparison with the other two systems on the heat basis adopted by Mr. Harvey a balance-sheet has been drawn up and is appended to these remarks showing the yield of molten brass which could be obtained if the whole of the combustibles available on carbonisation were employed for the melting of brass with furnaces of the efficiencies cited by the author.

Producer Gas.—It is not quite clear whether the author has in mind the semi-producer type of furnace or an appliance involving a producer as a separate entity. In view of the statement on page 6 of the paper it would appear that he is referring to the latter type. If we consider the data published in this connection by Mr. Harvey, we arrive at somewhat peculiar figures, which, if correct, deserve more emphasis than they have received.

The producer efficiency is presumed to be 90 per cent., and the gas consumption figures show a furnace efficiency at 9.7 per cent., so that the overall fuel efficiency is 8.7 per cent. and the Harvey ratio becomes 1 to 11.5.

It is stated that 60 cub. ft. of gas of 135 British thermal units per cubic foot are obtained per pound of coal fired. The total heat value of the gaseous fuel is then 8,100 British thermal units. With a producer efficiency of 90 per cent. this means that the calorific value of the coal employed is only 9,000 British thermal units per pound. In that event, why debit the system with a fuel charge of 1*l.* per ton when the other systems employing coal of 13,000 British thermal units are only debited similarly with 1*l.* per ton. To make the gas data quoted agree with the 13,000 British thermal units fuel discussed under the other headings would involve a producer efficiency of 62 per cent. On this basis the overall efficiency of the system becomes 6.2 per cent. and the Harvey ratio 1 to 16.

If, on the other hand, we assume a larger producer plant, supplying several foundries, with a producer efficiency of 75 per cent. there would be a yield of 82 lb. to 85 lb. of ammonium sulphate and about 15 gallons of tar per ton of coal gasified, and the overall

fuel efficiency of the system would be 7½ per cent. For efficient working the melting furnace would have to run continuously, and adequate regenerators would be required. If the producer were run solely with a view to producing the best gas for metal-melting furnaces, and the steam saturation of the blast reduced accordingly, a somewhat higher yield of molten brass would result, with a smaller quantity of sulphate.

The attached balance-sheet, drawn up from the author's data, shows little difference between powdered coal and town gas, both of which would appear to be preferable to the producer gas system if Mr. Harvey's premises are correct.

Fuel Balance-sheet for the Three Systems.

Dr. (for each system.)

	Million B.Th.U
1 ton coal of 12,960 British thermal units per pound	29.03
(Capable of melting 111,238 lb. of brass at 261 British thermal units per pound.)	

Cr. (Powdered Coal.)

(Gross efficiency, 15 per cent.; net efficiency, 13.5 per cent.)

	Million B.Th.U.	Lb. of Brass.
Thermal energy usefully employed	3.919	
Capable of melting ...		15,015
Cr. (Coal gas.)		
11 cwt. coke, 12,000 British thermal units per pound	14,784,000	
*Employed in tilting furnace of 15 per cent. efficiency would melt		8,498
16 gallons tar, 171¼ lb., at 20,000 British thermal units per pound... ...	3,425,000	
Employed in oil furnace of 15 per cent. efficiency would melt		1,968
10,800 cub. ft. gas at 550 British thermal units net per cubic foot	5,940,000	
Employed in gas furnace of 15 per cent. efficiency would melt		3,414
Total	24,149,000	13,880
Plus ...	35 lb. ammonium sulphate. 4.5 lb. sodium ferrocyanide.	

* This fuel does not commend itself generally for such furnaces; but is a recognised source of energy for other heat treatment processes which enable the above thermal efficiency to be obtained.

Cr. (Producer gas.)		
(After Harvey.)		Lb. of
60 × 2,240 cub. ft. gas, of 135 British thermal units	B.Th.U. 18,144,000	Brass.
With a furnace consumption of 20 cub. ft. per pound brass would melt		6,720
If we assume—		
75 per cent. producer efficiency — then heat value of gas	21,772,500	
With furnace efficiency of 10 per cent. would melt 15 gallons of tar, 160½ lb., at 20,000 British thermal units	3,210,000	8,342
Employed in oil furnace of 15 per cent. efficiency, would melt		1,845
Total	24,982,500	10,187
Plus ...	85 lb. ammonium sulphate.	

Yours faithfully,
HAROLD HARTLEY,
(Of the Richmond Gas Stove and Meter Company, Limited).
Academy-street, Warrington, Lancashire,
September 27, 1917.

To the Editor of Engineering.

Sir,—Mr. L. C. Harvey, in his recent paper, entitled "Fuel Economy in Brass-Melting Furnaces," read at the autumn meeting of the Institute of Metals on September 19, brings forward some points of rather far-reaching effect, and it is questionable whether he is at all justified in adopting the basis of calculation which he has done, as he says his object is to consider the question from the standpoint of conservation of coal supplies. Is he justified in proposing that coal shall be burnt directly for any purpose at all? The industrial development of this country is inseparably bound up with its resources of high-grade fuel, necessary for the production of mechanical, thermal or chemical energy. When it is borne in mind that in Norway, a country only a few hundred miles distant, electrical energy is regularly produced and transmitted at a charge not exceeding 2*l.* per electrical horse-power-year of 8,760 hours, the competition which this country may experience in the future can be imagined.

Coal users throughout the world have often regarded this material solely from the point of view of a fuel, nevertheless realisation is growing even among the masses that it is possible to obtain from coal materials of importance for other purposes, so it is rather surprising that Mr. Harvey should have taken his somewhat limited view of the matter in considering this question.

For example, the contention that the process of carbonisation for the manufacture of coal gas cannot show any economies from the standpoint of conservation of coal supplies does not appear to be borne out by a critical examination of the analysis drawn up by Mr. Harvey. Rather, in view of the comparative results obtained, is there not some reason for asking whether there is any justification for regarding our natural fuels merely as sources of thermal energy?

Whilst the author takes cognisance to some extent of the coke produced in carbonisation, he would appear to have overlooked the other by-products which gas-works practice yields, and these are neither few nor unimportant in peace time, but are essential to the nation in time of war. As I pointed out in my lecture at the Royal Society of Arts in April last, in view of the figures I then gave of the coal reserves of the principal commercial countries and the conclusion of the Royal Commission on Coal, the most economical use of our remaining supplies is a very practical and urgent question.

I do not wish to express any view in regard to the merits of the particular process of carbonisation now in vogue for the preparation of town gas, nevertheless I feel that the case for carbonisation, or some similar preparation of natural fuel, prior to using it as a source of heat energy, is universally recognised. Gas-works coke is not ideal for all industrial operations, but, on the other hand, there is an increasing demand for this fuel for employment in metal-treating furnaces. The semi-producer type of furnace is, for example, very largely used in muffle and open-flame furnaces for the heating of steel billets. Producer gas finds a vocation in furnace heating with much success where adequate regeneration or recuperation is ensured, and of course the production of this producer gas need not involve the utilisation of raw fuel.

The subject is obviously one which cannot be adequately discussed in a brief communication. My object is merely to draw attention to the fact that there are factors, apparently ignored in Mr. Harvey's analysis, which are of great importance in any consideration of the economical bases of the use of any particular type of fuel.

One other point: the author states that the reverberatory furnace is thermally of low efficiency. I think this statement will not receive universal support. If the furnace be used only intermittently the best results from the point of view of fuel consumption are not to be expected, but it is generally realised that, viewing the question solely from the thermal standpoint, open-flame furnaces should be capable of giving better results than fuel furnaces using crucibles. By this statement it is not meant that necessarily the open-flame furnaces on the market are more efficient than particular designs of crucible furnaces, which have, especially in this country, been very considerably experimented upon in recent years, but that it is easier to transmit thermal energy to the metal with direct flame contact than when this does not occur.

Yours faithfully,
H. M. THORNTON.
132, Queen Victoria-street, London, E.C. 4.

THE ANALYSIS OF INCLINING EXPERIMENTS.

To the Editor of Engineering.

Sir,—The article in your issue dated September 28, 1917, on the analysis of the results of inclining experiments, by Mr. C. Frodsham Holt, raises several interesting points, and in view of the importance of the subject I should be glad if you can find space for the following remarks.

The case assumed by Mr. Holt, viz., that of a ship extremely tender or initially unstable, would rarely arise unless the inclining condition of the ship differed considerably from any conceivable working condition. Elaborate calculations are required to get the stability when completed, these being due to the large additions of weight and (frequently) to the large difference between the trim in the two conditions. Moreover, as pointed out in the article, an element of danger is introduced; in one case known to the writer so violent a lurch was produced when the ship listed from one side to the other while shifting the weights, that all the men left the vessel, and were only induced with great difficulty to return and continue the experiment.

Whenever possible it is considered that the vessel should be brought, by adding ballast before inclining, to a condition where reasonable stability is obtained and the trim is approximately correct; the subsequent calculations are then simplified and the chance of error reduced. (An interesting and exceptional case is that of a floating dock, whose stability when inclined light is so enormous that no result of value can be obtained; it may then be desirable to add water ballast until the pontoon deck is submerged and the metacentric height reduced, although the subsequent calculating work is slightly increased thereby.) Reverting to ships, in cases where this procedure is not practicable Mr. Holt's method can be used; though in warship forms; at least, the "wall-sided formula" by no means accords with the G Z curve at small angles; from an analysis of these curves for several ships it appears that for B M, or ρ in the formula, should be substituted a constant varying between 0.4 B M and 0.5 B M. Fortunately, the final result is not very sensitive to the exact value of this constant, so that this method, although possessing many disadvantages, should be sufficiently accurate if reasonable care be taken in the subsequent calculations.

Finally, the three equations (2), (3) and (4), are rather difficult to solve (incidentally a misprint has occurred in (2), the third term of which should read $-2X_0/\rho$), and some may prefer the following graphical process:—

Construct, for a series of different values of G M, curves of X or G G¹ (horizontal shift of G), by multiplying the ordinates of the G Z curve up to the angle of heel required by sec θ. If no G Z curve is available, a G G¹ curve can be constructed from the "wall-sided" formula (1). On a piece of tracing paper draw, on the same scale as above, horizontal lines A H B, C L D, E K F, and vertical lines A C E, H L K, B D F, so that A C = C E = X, H B = θ, A H = θ_0. Place the paper over the curves, and keeping B and E on any one of them, slide it until A B is horizontal; then note the distance of L above or below the corresponding G G¹ curve. Repeat this with the different curves, and plot the "L distances" so obtained on a base of assumed G M. The intersection of a curve drawn through these points with the base will give the desired metacentric height.

Yours faithfully,
October 1, 1917. L. WOOLLARD.

To the Editor of Engineering.

Sir,—With your permission I should like to suggest to Mr. Frodsham Holt the advantage in ship geometry of drawing the cross-section of his ship in the upright position on the page, and then drawing the water lines inclined at any desired angle.

It is easy to tilt the page or blackboard to bring any water-line horizontal.

The various curves, of buoyancy, metacentre, &c., will then appear as fixed curves in the ship. In a diagram of a mechanical problem it is often a great simplification to leave the vertical line to be inserted last of all.

Yours sincerely,
Staple Inn, September 29, 1917. G. GREENHILL.

THE BEDPLATES OF TURBINE UNITS.

To the Editor of Engineering.

Sir,—I am much interested in the letter of Mr. N. L. Snow, of the Terry Steam Turbine Company, in your issue of September 21, page 313, in connection with alignment of bedplates. The education of the public by manufacturers in a matter of this kind is a very slow business, and I consider that it would be time well spent if all the technical engineering schools were to devote a lecture or two each year to the principles and methods of alignment, and the consequences to high-class machinery if the necessary precautions are neglected. I do not think it is fully realised, except by manufacturers of high-speed machinery, how much trouble is caused by bad alignment, and how much fine machinery is practically ruined, or has its efficiency seriously impaired, by lack of knowledge on the part of erectors.

A curious point about the matter is that all erectors seem to be extremely "touchy" if one makes any suggestions in the matter of alignment. They seem to consider that the matter is one of the elementary things that it is ridiculous even to mention in their presence; yet, in spite of the most careful instructions and precautions on the part of my company, and the use of very heavy, deeply-ribbed bedplates, it has been found that practically all mechanical troubles and undue wear are caused by jobs not being properly set up by the customers' erectors.

Another curious feature is the persistence of the idea that a set need not be carefully aligned if it has a flexible coupling. Nothing is more productive of harm than to have an erroneous idea of this kind widespread among erectors, as this undoubtedly is.

If you would be good enough to write a leading article on the subject for the special attention of all those interested in the teaching of engineering and mechanics, I consider you would be helping very considerably in the education of erectors and machinery users on a subject that is of much greater importance than is generally realised.

Yours faithfully,
J. W. W. DRYSDALE, JUNR.
"Bon-Accord" Works, Yoker, Glasgow, W.,
October 2, 1917.

TERMS OF CONTRACTS.

To the Editor of Engineering.

Sir,—The very able article in your issue of the 21st inst. on the subject of a new basis of Government and other contracts is of immense importance and interest at the present time, when competitive *à forfait* offers are quite impossible. It is generally admitted that contracts based on actual expenditure, with a percentage added to cover establishment charges, on-costs, and profit, are undesirable in that they offer a premium to inefficiency, but in many cases in the past where the contracting firm has been of the highest standing and integrity contracts on this basis have been carried out with eminent success to all parties. The suggestion now put forward in the article referred to is that actual expenditure in wages and materials is to be paid, plus a lump sum to cover establishment charges and profit, and it is difficult for one to see how this is more satisfactory than the old cost plus percentage basis. It is clear that the lump sum for establishment and profit must be arrived at by a percentage on the estimated cost of labour and materials, and, when arrived at, becomes a lump sum which surely would require some adjustment in the event of the original scope of the work being reduced or increased.

When this lump sum is fixed it becomes the only part of the transaction which matters to the contractor, he having no financial interest in the cost of labour and materials, but only in the expenditure for establishment,

and the lower this can be brought the better for his pocket, and the tendency would be to reduce establishment to such an extent that the cost of labour and materials might suffer enormously.

The object to aim at seems to be to adopt a basis by which the Government and the contractor are pulling at the same end of the rope, and this can only be done upon some form of bonus, by which the more the contractor earned the better for the Government. The firm of public works contractor of which the writer is a member has worked for many years on a system of bonus with their men, which has had some really marvellous results.

I would suggest the following basis of contract. Assume that the Government require a ship or a number of ships to the same design. This design, with specification, is submitted to various contractors, who are asked to send in offers on the following lines :—

1. Estimate of total cost of ship, including profit.
2. Estimate of cost of labour.
3. Estimate of cost of material.
4. Estimate of cost of establishment and all other charges.
5. A lump sum for profit.

When these offers are received the Government would examine them, together with an estimate prepared for them by the designer of the ship, and the most favourable offer would be accepted in this way, that all actual expenditure is to be under Government control, and when the ship is completed and handed over, if the total actual cost is less than (1) of estimate the difference is to be divided between the Government and the contractor, one moiety to each, if the cost is more, one-half of the difference is to come off (5) until this lump sum is wiped out.

In this way the contractor, in making his estimate, would have to be careful that the estimate of total cost (1) is sufficient, otherwise he would risk doing the work without any profit; on the other hand, if his estimate (1) was too high, his offer would compare unfavourably with others and would be rejected. Once having the work, his interests and those of the Government would be identical, and the less the actual cost the better for all.

Yours faithfully,

September 27, 1917. M.Inst.C.E.

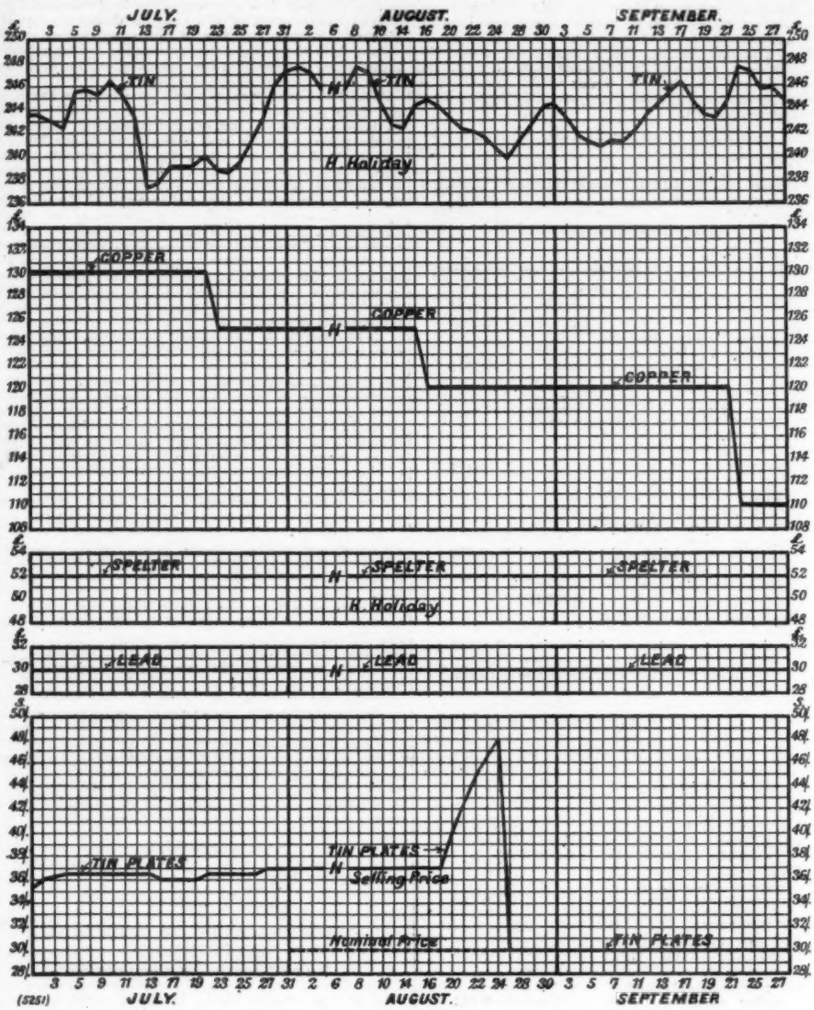
Personal.—Messrs. The Hydraulic Gears, Limited, Beaver-lane, Hammersmith, London, W. 6, inform us that they have acquired from Messrs. Compayne, Limited, the British rights for the manufacture and sale of Hele-Shaw hydraulic pumps, motors and transmission gears.—In consequence of the Government having requisitioned St. Stephen's House for the accommodation of the Ministry of Food, Sir Alex. Binnie, Son and Deacon have removed temporarily to 9, Victoria-street, Westminster, S.W. Their telephone number remains unaltered, but their telegraphic address is now "Arbintro, Vic., London."—Mr. Macmillan, Garswood, Southport, director of the Calico Printers' Association, Limited, has joined the board of the Manchester Steam Users' Association.

The late Mr. Bernard George Arkwright.—We regret to have to announce the death, which occurred on Tuesday, the 2nd inst., of Mr. Bernard George Arkwright. Mr. Arkwright was born in 1861, and was the son of the late Rev. George Arkwright. He was educated at Harrow and Bonn University. He served his apprenticeship at the Elswick Works of Sir W. G. Armstrong, Whitworth and Co., Limited. He had since then been connected with the engine works department of that firm, first as assistant manager and later as manager. Mr. Arkwright was a member of the North-East Coast Engineer Employers' Federation and of committees and conciliation boards. He became a member of the Institution of Civil Engineers in 1902, and in 1903 a member of the Institution of Mechanical Engineers. His two sons are captains in the army.

Ground Screw Threads.—In a recent issue of *The American Machinist* Mr. E. A. Suverkrop describes a process by which precision taps and screw gauges are produced by grinding the threads out of hardened stock, thus eliminating the risk of warping which arises when taps and gauges are made out of soft material and subsequently hardened. The process has, it is stated, been used for making taps and gauges ranging from 0.157 in. in diameter, with 36 threads per inch, up to 4 in. in diameter with 4 threads per inch. In the case of the larger sizes the grinding process is merely used for finishing the tap, which is roughed out in the soft state, hardened, and then brought true to pitch and form by grinding. With small sizes, however, the thread is generated from start to finish entirely by the grinding wheel. The grinding wheels used were supplied by the Norton Grinding Company, and have grains listed as 38–100 to 38–200, grades J and I. The blanks to be cut are mounted between the centres of a cataract lathe, which is fitted with a buttress-threaded hob, which gives the traverse to the grinding wheel. This wheel is independently driven, and mounted on its saddle is a trueing device consisting of two diamond cutters, which can be traversed over the cutting faces of the wheel so as to maintain the accuracy of the angle between the flanks and the threads. The wheel is trued up on starting work and again when the work is within $\frac{1}{16}$ in. of the finished size, and, finally, just before finishing, when the work is but 1 mil or 2 mils over size. The machine, which is due to the engineer of the Fresh Machine Works, Brooklyn, is stated to produce work accurate in every dimension within a limit of 0.0002 in. and 0.0003 in.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

(Specially Compiled from Official Reports of London Metal and Scotch Pig-Iron Warrant Markets.)



Note.—In the diagram above the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange, as far as they have been reported, for "fine foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. The prices are per ton. The price of tin-plates is per box of I.C. cokes free on board at Welsh ports. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each. On July 7, 1916, the Minister of Munitions issued a list of maximum prices and regulations governing the dealing in certain metals, &c.; thus the price of hematite pig was fixed at 6*l.* 2*s.* 6*d.*, Scotch at 5*l.* 14*s.*, and Cleveland at 4*l.* 11*s.* 6*d.* per ton. Ship-plates were priced at 11*l.* 10*s.*, and heavy steel rails at 10*l.* 17*s.* 6*d.* per ton. These quotations are still in force. (For official regulations see page 45, vol. cii.)

German War Profits.—It is not only the steel and iron industry which is earning record profits in Germany at present; the Ammendorf Paper Mills have declared a dividend of 36 per cent. for the year 1916–17, against 26 per cent. for the previous year. It has also been urged that the State should interfere against the rise in the price of paper.—The United Chemical Works, Charlottenburg, paid a dividend for last year of 27 per cent., the same as for the preceding year, but in addition the shareholders obtain a bonus of 18 per cent. This favourable result is principally due to the manufacture of an important material which is being technically exploited on a large scale. The glycerine manufacture was being solely worked for the authorities, and all independent purchase of raw material for this and the soap business had come to an end, all going through the official bureaux; the lanoline manufacture was being more and more hindered through shortness of raw material and packing material.—The Lovitsch Zinc Works at Kattowitz had net profits of 897,822 marks for the last financial year, against 101,995 marks for the previous year, the writings-off being materially increased.—The German Mineral Oil Company, the shares of which are principally held by the German Rock Oil Company (the Deutsche Erdöl Company), and a smaller portion by the German Petroleum Company, is reported to have paid 25 per cent. for last year, against 6 per cent. for the previous year.

Shipbuilding in Sweden.—The director of the Lindholmen yard states that the Swedish shipyards will be fully employed for several years with contracts for new vessels, the Lindholmen yard, for instance, till 1922. There is a marked shortage of skilled labour, and it is very difficult to procure the necessary raw material. England does not supply anything, and Germany demands 500 kronor to 600 kronor for steel plates which, on the German market, only cost 300 marks. The price which Swedish shipyards at the present time have to ask for new contracts is therefore between 1,100 kronor and 1,200 kronor per ton, a price which is bound to have a decidedly deterrent effect. German shipyards ask 600 kronor per ton, although they use Swedish ore. The director of the Lindholmen yard has not much faith in the building of standard vessels, as far as Swedish shipbuilding is concerned, as a means of increasing the output, because Swedish shipyards are arranged for the building of special types, and the introduction of a uniform type for the whole country would hardly lead to a satisfactory result. In spite of all the difficulties arising from the war, the building of the second and third ironclad of the Sverige type has been duly proceeded with; the Drottning Viktoria will be launched from the Götha shipyard in Gothenburg in the middle of September, and the Koning Gustaf V will be launched from the Kockum yard, Malmö, some three months later. (1 krona = 1*s.* 1½*d.*)

NEW EXPERIMENTS ON SHOCK TESTS AND ON THE DETERMINATION OF RESILIENCE.*

By GEORGES CHARPY and ANDRÉ CORNU-THENARD (Paris).

(*Concluded from page* 348.)

III. INFLUENCE OF DIFFERENT VARIABLES WHICH MAY INTERVENE IN SHOCK TESTS.

Being possessed of very homogeneous material able to give results extending over the entire scale of ordinary resilience, the authors were in a position to study the influence of the different variables which are capable of intervening in the course of shock tests. It was no longer necessary to take into consideration, each time, a large number of more or less discordant results and to take the mean by invoking the application of the law of averages. They were therefore able to remain content, in the course of the experiments, with breaking at least five bars per experiment. The method of operating is detailed below :—

1. *Definition of the Method of Investigation adopted.*—The object in view was to ascertain if the variation of one of the conditions of testing had any appreciable influence on the results obtained with any one given test-piece. For this purpose a series of ten bars, as uniform as possible, was made up, and the average resilience R_m of the series was ascertained by breaking, in the normal manner, five of these bars. It may well be assumed that the same figure for $R_m \pm$ approximately n per cent. should be obtained on testing the remaining five bars in the same manner.

The particular factor to be investigated is then varied, and the remaining five bars are broken under the new conditions prevailing, which will yield an average resilience P_m.

If a variation in the average resilience occurs it is then regarded as due to the influence of the change effected, and this influence is regarded as negligible in practice when the difference $R_m - P_m$ is in the neighbourhood of the n number per cent. selected as a criterion of the accuracy of the results of the experiment.

These preliminary details settled, the authors investigated, in succession, the influence of the following variables : depth of fall, weight of drop-weight and of anvil-base, type of testing machine and type of notch.

2. *Influence of the Height of Fall.*—The influence of the height of fall of the drop-weight in shock tests is often considered as exerting an important share in the results ; it is, however, regarded with widely varying views. Mr. Belanger, for instance, claims decreasing resilience from unity to double and even more when the height of the fall is reduced from 4 m. to 1 m., while, on the other hand, Mr. Fremont gives differences in respect of certain steels which, although not numerically recorded, he appears to regard as even more excessive than those recorded by Mr. Belanger, but in the opposite direction entirely.

The tests here given by the authors were carried out on two different pendulum drop-weight machines, one having a maximum height of fall of 6.45 m. and the other 3.87 m. The first table on page 372 gives all the factors revealed during the course of the experiments, the bars, which measured 30 by 30 by 160, being notched with the Copenhagen notch.

These results show that the rate of shock is practically negligible within the limits to which the authors confined themselves (11.25 m. to 3.40 m.), and which do not exceed those of the appliances generally employed in the testing laboratory.* The indifference displayed by the results of the shock test to the height of fall are easily understood, under ordinary conditions, if instead of considering rate of impact (or height of fall) the mean rate of deformation be taken into consideration.

Consider, as a matter of fact, the results given in the table on page 372. It is seen, for example, in the case of the steel P, that the height of fall may vary in the ratio of 7 : 1, and that at the same time the residual rate of speed, after impact, may vary in the ratio of 12 : 1 without the average duration of the test varying more than $\frac{15}{10,000}$ to $\frac{62}{10,000}$ of a second ; it is not surprising, therefore, that the resilience result does not record this variation to any appreciable extent.

3. *Influence of the Weight of the Drop-Weight and that of the Anvil-Base.*—In view of the difficulty in accurately defining precisely what is meant by the expression "weight of anvil-base," the authors decided to institute comparisons between two machines of the same type, differing, however, considerably in their dimensions ; the question of height of fall being eliminated, the two only variables whose influence could affect the results are thus the weight of the drop-weight and of the anvil-base. With this object in view two pendulum drop-weight machines were employed, one of 307 kilogrammetres (weight of drop-weight, 96.25 kg. ; height of fall 3.87 m. ; and distance apart of supports, 80 mm.), and the other 47 kilogrammetres (weight of drop-weight, 32.14 kg. ; height of fall, 1.49 m. ; and distance apart of supports, 80 mm.).

The ten test-bars (20 mm. by 20 mm. by 107 mm., notched to one-half) of the same series were divided into two sets of five each. One set was tested on the 307-kilogrammetre machine ; the other set on the 47-kilogrammetre. The results obtained were as follow :—

—	307-Kilogrammetre Machine.	47-Kilogrammetre Machine.
R_m	18.61	19.90
ϵ_m	± 1.04	± 1.70
E_m	5.6 p.c.	8.5 p.c
Maximum divergence	20.20 to 16.52	21.96 to 16.99

Taking into consideration the mean relative divergences determining the accuracy of the test, these two results may be regarded as being practically identical. However, as the pendulum drop-weight machine of 47 kilogrammetres employed was one of an old pattern, and appeared to have suffered some deterioration in the course of these experiments, during which somewhat heavy demands were made upon it, the same experiments were repeated on a new machine, the dimensions of the test-bars being reduced to 15 mm. by 15 mm. by 80 mm. In this second series of experiments the authors employed (Fig. 5) : (1) the same pendulum drop-weight machine of 307 kilogrammetres as described above (distance apart of supports, 60 mm.) ; (2) a 30-kilogrammetre pendulum drop-weight machine (weight of drop-weight, 22.31 kg. ;

Fig. 5

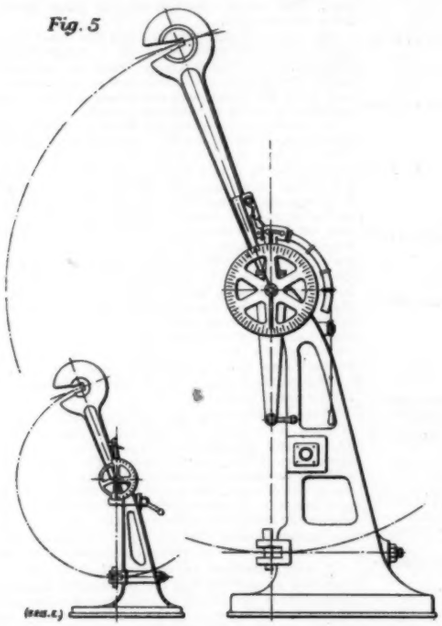


FIG. 5.—Diagram of the two pendulum drop-weight machines employed for studying the influence of the mass of the falling weight and the weight of the anvil-base.

On the right-hand side the 307-kilogrammetre pendulum drop-weight machine :

Weight of falling body (kilograms)	96.25
Height of fall (metres)	3.87
Weight of frame (kilograms)	1800

On the left the 30-kilogrammetre pendulum drop-weight machine :

Weight of falling body (kilograms)	22.31
Height of fall (metres)	1.45
Weight of frame (kilograms)	190

Fig. 6.

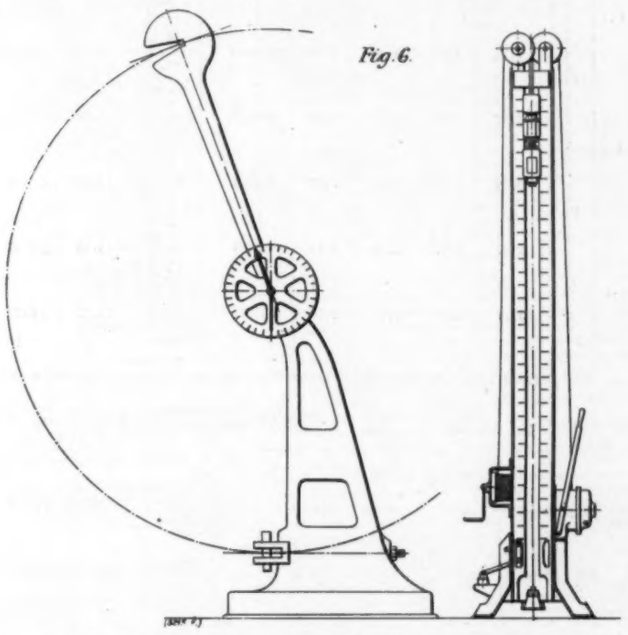


FIG. 6.—Diagram of a pendulum drop-weight machine and a vertical drop-weight machine employed to study the comparability of these two types of machines.

To the left a 307-kilogrammetre pendulum drop-weight machine :

Weight of falling body (kilograms)	96.25
Height of fall (metres)	3.87

To the right a vertical drop-weight machine :

Weight of falling body (kilograms)	18.28
Height of fall (metres)	3.05

This result may, besides, be likened to those obtained by Messrs. Sarrau and Vieille in their celebrated experiments on the measurement of explosive pressures, namely, that the deformations produced on the crushed cylinders, per given pressure, remained practically identical even when the rate of applying the pressure varied from $\frac{1}{10}$ to $\frac{2}{10,000}$ of a second. One of the authors† has already shown that in order that the results of the tests should be influenced to an appreciable extent it was necessary that the average duration of the deformation should vary from 2 minutes or 3 minutes to 1 second. Under such conditions the diminution of the crushing reaches 8 per cent. to about 10 per cent. of its amount. The durations of deformation brought into play in the course of the authors' investigations resemble, therefore, in respect of order of magnitude, those taken into consideration by Messrs. Sarrau and Vieille, and their conclusions have but the effect of extending to bend tests, for a very considerably less time-interval, the correction suggested by those observers.

Drop-Weight Machines.	Series of Bars.	Individual Resiliences.	R_m.	ϵ_m.	E_m.	Maximum Divergence.
Kgm.		Kgm.			Per cent.	
307	C. 11 I	19.72	18.67	±0.65	3.5	19.72–17.48
	C. 11 II	18.97				
	C. 11 III	17.48				
	C. 11 IV	18.97				
	C. 11 V	18.22				
30	C. 12 I	19.31	17.93	±0.86	4.8	19.31–15.93
	C. 12 II	18.44				
	C. 12 III	15.93				
	C. 12 IV	17.77				
	C. 12 V	18.22				

* Paper read before the Iron and Steel Institute, September 21, 1917.

* This result was fully confirmed by experiments carried out at the Conservatoire des Arts et Métiers (see report reproduced at the end of this paper).

† G. Charpy, "Note on the Calibration and Working of Crusher-Manometers" ; *Mémorial de l'Artillerie de la Marine*, 1898, vol. xxvi, p. 115.

RESULTS OF SHOCK TESTS WITH VARYING HEIGHT OF FALL OF DROP-WEIGHT.

Series.		Height of Fall.	Rate of Speed. Initial.	Rate of Speed. Residual.	Rate of Speed. Average.	Duration of Test.	Individual Resiliences.	R_m.	ϵ_m.	E_m.	Maximum Divergence.
		metres.	metres.	metres.	metres.	seconds.	kgm.			per cent.	
Steel O	6 I.	6.45	11.25	10.28	10.76	0.0012	9.84	9.76	±0.61	6.2	10.31 to 8.91
	6 II.						8.91				
	6 III.						9.38				
	6 IV.						10.31				
	6 V.						10.31				
	6 VI.						9.84				
	7 I.	4.31	9.20	8.20	8.70	0.0015	9.86	9.55	±0.71	7.5	10.79 to 8.01
	7 II.						8.01				
	7 III.						8.94				
	7 IV.						9.86				
	7 V.						10.79				
	7 VI.						9.86				
	8 I.	2.20	6.57	5.11	5.84	0.0022	10.67	9.97	±0.34	3.4	10.67 to 9.29
	8 II.						9.29				
	8 III.						9.62				
	8 IV.						9.97				
	8 V.						10.32				
	8 VI.						9.97				
Steel J I ..	1	3.87	8.87	7.55	8.21	0.0036	18.10	17.98	±0.13	0.7	18.10 to 17.81
	2						17.81				
	3						18.10				
	4						18.10				
	5						17.81				
	6	1.15	4.83	1.83	3.33	0.0090	18.15	17.28	±0.56	3.2	18.15 to 16.68
	7						16.68				
	8						17.08				
	9						17.81				
	10						16.68				
Steel P I ..	1	3.87	8.87	8.14	8.50	0.0015	10.08	9.98	±0.15	1.5	10.08 to 9.59
	2						9.59				
	3						10.08				
	4						10.08				
	5						10.08				
	6	0.58	3.44	0.70	2.07	0.0062	9.63	9.79	±0.19	1.9	10.21 to 9.51
	7						9.85				
	8						10.21				
	9						9.75				
	10						9.51				
Copper ..	1	3.87	8.87	7.99	8.43	0.0035	12.35	12.14	±0.27	2.2	12.61 to 11.83
	2						12.09				
	3						11.83				
	4						12.61				
	5						11.83				
	6	0.71	3.80	1.25	2.50	0.0120	11.34	11 12	±0.29	2.6	11.42 to 10.71
	7						11.42				
	8						11.34				
	9						10.81				
	10						10.71				

COMPARABLE TESTS ON PENDULUM DROP-WEIGHT AND VERTICAL DROP-WEIGHT MACHINES.

Type of Apparatus.		Height of Fall.	Weight of Mass.	Description of Bars.		Individual Resilience.	R_m.	ϵ_m.	E_m.	Maximum Divergence.
		m.	kg.			kgm.			per cent.	
Pendulum machine	drop-weight	3.87	96.25	P II	1	10.44	10.39	±0.08	0.7	10.44 to 10.19
					2	10.44				
					3	10.44				
					4	10.44				
					5	10.19				
Vertical machine	drop-weight	3.05	18.28	P II	6	9.95	9.65	±0.23	2.4	9.95 to 9.20
					7	9.20				
					8	9.67				
					9	9.52				
					10	9.91				

COMPARABLE TESTS ON CHARPY PENDULUM MACHINE AND GUILLERY ROTARY MACHINE (FIG. 7, PAGE 373).

Description of Machine.	Rate of Impact.	Average Resilience.	Average Divergence.	Relative Average Divergence.	Extreme Individual Resiliences.
Metal employed: Steel J. Type of bar: 10 × 10 × 53.3 (round notch, radius 0.7 mm.). Distance apart of supports: 40 mm. Number of bars in each series: 5.				per cent.	
Charpy pendulum machine of 30 kilogrammetres	5.519	18.55	±0.25	1.3	19.01 to 18.24
Guillery rotary machine of 60 kilogrammetres	8.858	18.4	±0.34	1.9	18.9 to 18.0
Metal employed: Steel J. Type of bar: 30 × 30 × 160 (Copenhagen notch). Distance apart of supports: 120 mm. Number of bars in each series: 5.					
Charpy pendulum machine of 300 kilogrammetres ..	9.637	18.78	±0.45	2.4	19.64 to 18.21
Guillery rotary machine of 275 kilogrammetres	8.858	20.45	±0.71	3.5	21.78 to 19.78

height of fall, 1.45 m.; distance apart of supports, 60 mm.). The weights of the frames of these were 1,800 kg. (the 307-kilogrammetre machine) and 190 kg. (the 30-kilogrammetre machine) respectively. It may be assumed that the weights of the anvil-bases are roughly proportional to those of the frames.

The complete table of results obtained is given at the foot of the preceding page.

In this case the homogeneity of the individual determinations in each series is thoroughly satisfactory, and the average resiliences do not differ from one another by more than 0.74 kilogrammetre, that is, say, by only 3.9 per cent. of the highest figure recorded.* It may, therefore, be concluded that, within the limits of accuracy reached in these experiments, the weight of the drop-weight and that of the anvil-base are without effect on the drop-test result. The results given above appear to the authors the more interesting in that, in these experiments, the two machines worked under altogether abnormal conditions, the large machine being unduly large for the work and the small machine unduly small. Thus while in the former the breakage of the test-bars barely absorbed one-tenth of the available energy, in the latter nearly the entire energy of the machine was absorbed.

4. *Comparability of Different Types of Machines.*—Having thus established the practical identity of the results obtained on shock testing with two machines of the same type, although differing considerably from one another in dimensions, the authors set themselves to investigate whether the different types of machines in use gave comparable results.

(a) *Pendulum Drop-Weight and Vertical Drop-Weight (falling weight) Machines compared.*—Their first experiments related to a pendulum drop-weight and a vertical drop-weight machine (Fig. 6, page 371). It was natural, therefore, in the first place, to seek to ascertain if, qualitatively speaking, comparable results were obtainable. With this object the authors formed a group of 4 n very uniform test-bars, and determined the average resilience of the set by breaking 2 n under a pendulum drop-weight. Assume T_m to be the average work which produced, within about 2 per cent., the fracture of these 2 n test-bars. They then calculated the height H at which it was necessary to liberate the drop-weight P of the vertical drop machine to satisfy the relation $PH = T_m$. This done, the weight P was allowed to fall—(1) From a height H $(1 - \frac{\lambda\lambda}{100})$ on n of the remaining test-bars. Neither of them underwent fracture. (2) From a height H $(1 + \frac{\lambda\lambda}{100})$ on the n test-bars remaining. They all underwent fracture.

The authors successively made P = 18 kg. and 75 kg. in the above instances. The results were uniform, despite the variation in the weight of the mass and in the height of the fall.

From a qualitative point of view, therefore, the pendulum drop-weight and the vertical drop-weight machines were perfectly comparable; it remained, therefore, to estimate numerically this comparability. For this the authors fixed on the vertical drop-weight machine an Amsler-Laffon recorder, which allows of the exact determinations of the rate of speed before and after fracture, and enables the energy absorbed in fracturing the bars to be calculated accordingly. The bars employed were of the Copenhagen type and measured 30 mm. by 30 mm. by 160 mm. In both machines the distance apart of the supports was 120 mm. The results obtained were as given on the second table on this page.

The two average resiliences differ from one another only by 0.75 kilogrammetre, or, in other words, by 7.1 per cent. of the higher figure. Given the makeshift nature of the arrangements, the results obtained with the vertical and with the pendulum drop-weight machines may be regarded as being in close agreement.

(b) *Pendulum Drop-Weight Machines and Rotary-Weight Machines.*—The experiments carried out at the Conservatoire des Arts et Métiers (see reports given in Appendix, paragraphs B, C and D) were made with Charpy drop-pendulum machines of 300 kilogrammetres and of 30 kilogrammetres, with a vertical drop-weight machine and with Guillery rotary machines of 275 kilogrammetres and 60 kilogrammetres. The authors will not detail afresh the results of the comparison of the pendulum drop-weight machines with the vertical drop-weight machine, which only served to confirm the results given in the second table on this page. They think, however, they are justified in emphasising the comparative tests made on the Guillery and Charpy machines respectively, the results of which were practically identical notwithstanding the essential difference in principle which characterises the two types of machine (Fig. 7). The results of these experiments are tabulated on the third table on this page.

There is here seen, once again, that the comparability of these two types of machines is highly satisfactory. The results recorded would be even more closely in agreement if the calculations of the experiments were in both instances carried out in the same manner, but the scales of the Guillery machines do not take absolutely into account the kinetic energy absorbed by the projection of the fragments of the test-bars after rupture, whereas the graduations of the Charpy pendulum machines take this energy into consideration (subtractive element).

It may therefore be concluded that the resiliences obtained on a given bar are practically identical, whatever, within the limits of ordinary practice, the height of the fall, the mass of the striking weight and of the anvil-base, and the type of apparatus employed. In order to render uniform the results of shock testing on any given bar it suffices to fix, beforehand and arbitrarily, certain material conditions, such as the distance apart of the supports, their contours, and the form of the knife-edges.

5. *Influence of the Type of Notch.*—The preceding experiments were carried out on test-bars of the Copenhagen type or on its immediate derivatives, the shape and dimension of the notch not having been as yet universally adopted. It appeared useful, therefore, to determine the influence of these conditions on the value of the energy of fracture per square centimetre.

With this object the authors experimented, therefore, on bars of 10 mm. by 10 mm. by 53.3 mm., and adopted the four types of notches described below:—

A.—Round notch: Residual section 10 by 5 = 0.5, punched with a die and saw-notched.

B.—Round notch: Residual section 10 by 7 = 0.7, punched with a die and saw-notched.

C.—Angular notch: Residual section 10 by 7 = 0.7, made with a tool and planed.

D.—Residual section 10 by 9 = 0.9, made with a blunt saw.

In the first table on the opposite page are summarised the results obtained on a pendulum drop-weight machine of 30 kilogrammetres.

This table brings out the following facts: Leaving out of consideration for the moment the angular notch, the resilience increases, for non-brittle metals, when the depth of the notch diminishes; it even doubles, with highly resilient steels, when we pass from a notch of mid-thickness to one of only 1 mm. in depth. With brittle metals the resilience varies very little with variations in the depth of the notch.

If the angular notch be considered, it will be seen that, for non-brittle metals, it yields results analogous with those obtained with a deeper round notch; for brittle metals the results are lower. These experiments, which are confirmed by the determinations carried out at the Conservatoire des Art et Métiers, emphasise the importance of an exact definition of the notch in classifying metals in the scale of resiliences. They show how some

* This series of determinations has been repeated at the Conservatoire, in analogous conditions, on a pendulum drop-weight machine of 300 kilogrammetres and one of 30 kilogrammetres. The average resiliences obtained were respectively 21.07 and 20.41 kgm.; they display a degree of agreement which strongly confirms that realised in the experiments recorded above.

experimenters, testing brittle metals only, have been led to the conclusion that, given bars of the same size, the area of the surface of fracture was a matter of indifference. They show, besides, how other experimenters who have exclusively used very superficial notches have attributed to ordinary metals resiliences greatly exceeding those generally credited to steels of the same grade. It is therefore indispensable to employ only perfectly defined types of test-bars—from a scientific point of view in order to be able to compare the results obtained in different laboratories; from a practical point of view in order, should need arise, to introduce into specifications factors having a precise signification.

The majority of experimenters unite in agreeing that the notch should have a definite geometrical form; it remains, therefore, to decide the depth and the radius. It certainly seems, judging from the results shown above, and in consideration of the advantage arising from strictly localising the fracture, that preference should be accorded to deep notches. The influence of the radius of the cylindrical orifice would appear to be of quite secondary importance.

Description of Metal.	Notches.	Energy of Individual Fracture.	Resilience.	R_m.	ϵ_m.	E_m.	Maximum Divergence.
		kg.	kgm			p. c	
Steel E (semi-hard carbon steel)	A	7.363	14.72	14.96	±0.28	1.9	15.45 to 14.49
		7.243	14.49				
		7.604	15.20				
		7.725	15.45				
		7.483	14.96				
	B	16.254	23.22	23.33	±0.29	1.2	23.79 to 23.02
		16.120	23.02				
		16.656	23.79				
		16.522	23.60				
		16.120	23.02				
	D	the test bar arrested the drop-weight	>30	>33	—	—	—
Steel J (semi-hard nickel steel)	A	6.080	12.16	12.48	±0.34	2.7	13.07 to 11.93
		6.308	12.62				
		6.308	12.62				
		6.538	13.07				
		5.967	11.93				
	B	11.157	15.93	16.69	±0.45	2.7	17.26 to 15.93
		11.421	16.31				
		11.819	16.88				
		11.952	17.07				
		12.085	17.26				
	C	9.342	13.34	13.19	±0.18	1.4	13.52 to 12.98
		9.088	12.98				
		9.088	12.98				
		9.215	13.16				
		9.469	13.52				
	D	20.545	22.82	22.37	+0.53	2.4	23.10 to 21.13
		20.792	23.10				
		20.296	22.55				
		20.045	22.27				
		19.025	21.13				
Steel P (semi-hard chromium-nickel steel)	A	2.567	5.13	4.76	±0.15	3.3	5.13 to 4.63
		2.313	4.63				
		2.313	4.63				
		2.397	4.79				
		2.313	4.63				
	B	3.954	5.64	5.70	±0.07	1.2	5.79 to 5.64
		4.054	5.79				
		4.054	5.79				
		3.954	5.64				
		3.954	5.64				
	C	2.481	3.54	3.32	±0.08	2.5	3.54 to 3.18
		2.313	3.30				
		2.230	3.18				
		2.313	3.30				
		2.313	3.30				
	D	5.304	5.89	5.36	±0.22	4.2	5.89 to 5.06
		4.875	5.41				
		4.665	5.18				
		4.770	5.30				
		4.561	5.06				

6. *Influence of the Dimensions of the Test-Bars and the Application of the Law of Similitude to Shock-Tests.*—It would obviously be desirable to adopt a single standard of test-bar for the study of metals under shock, but this solution conflicts in practice with genuine difficulties, which lead to the need of several types of test-bars of different dimensions, as are used, for instance, in tensile tests.

It is necessary, under such conditions, to ask whether, for a given metal, any simple relationship exists between the resiliences as determined on test-bars of different shapes. It had been thought, in the first instance, that in order to obtain comparative results it would suffice to employ notched test-pieces of geometrically similar shapes. The last table on page 348 *ante* decisively invalidates this view, and shows that the resilience, even in the same metal, varies to a considerable extent according to whether it be determined on test-bars measuring 30 by 30 by 160, or on test-bars measuring 10 by 10 by 53.3. This variation always takes place in the same direction, whether the metal be steel or copper, the resilience increasing with the dimensions of the test-bars. The ratio between the results itself undergoes modification, rising from $\frac{3}{4}$ for the least brittle steel to $\frac{1}{2}$ for the most brittle, and to $\frac{1}{3}$ for copper. This fact has, indeed, been previously noted by many observers of various nationalities, who have carried out, independently of one another, numerous experiments which agree completely, as is shown in the report presented by one of the present authors* at the New York Congress in 1912.

* Georges Charpy, "Report on Shock Tests and on the Work of Committee 26." (New York Congress, 1912); *Association Internationale pour l'essai des matériaux*, IV$_1$, pp. 3 *et seq.*

A theoretical investigation published in 1911 by Captain Mimey* concludes, from the point of view now under discussion, that the deformation of the bending test-bars B_1 and B_2, whether notched or not, and geometrically similar according to the similitude relation α, will absorb T_1 and T_2 energy, which will be to each other as the cube of the homologue dimensions, if the striking weights M_1 and M_2 of the drop-weight machines, the heights of fall H_1 and H_2 and the distances between supports D_1 and D_2 comply respectively with the conditions:—

$$\frac{M_1}{M_2} = \frac{\sqrt{H_1}}{\sqrt{H_2}} = \frac{D_1}{D_2} = \alpha.$$

This is, therefore, the ratio sought between the resiliences R_1 and R_2.

The authors' experiments appear, unfortunately, to foreshadow that this ratio, seductive as it is by reason of its simplicity, does not conform in a satisfactory manner to the conditions in practice. It has been brought

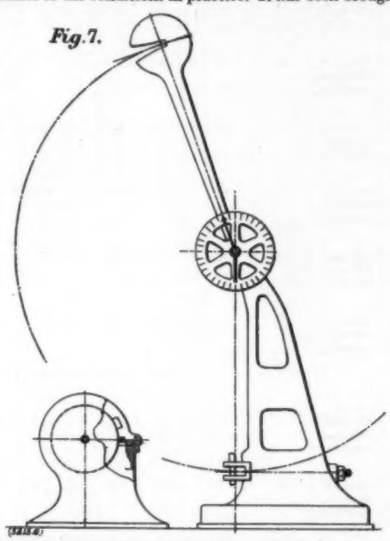


Fig. 7.

FIG. 7.—Diagram of the rotary Guillery drop-machine and of the Charpy pendulum drop-weight machine employed in investigating the comparability of these two types of machines.

On the right a pendulum drop-weight machine of 300 kilogrammetres.

On the left the rotary machine of 275 kilogrammetres.

Not only are the shape and dimensions of the machines employed very markedly different, but their very principles are dissimilar. In spite of this the resiliences obtained are perfectly comparable.

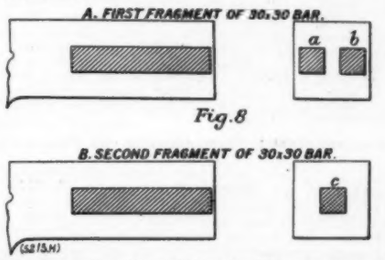


Fig. 8

FIG. 8.—Preparation of bars of 10 × 10 × 53 from the fragments of bars of 30 × 30 × 160.

out, in the course of this paper, that the work absorbed by the fracture of a test-bar is independent both of the mass of the falling weight and of the height of fall, or, in other words that the kinetic energy absorbed was practically independent of the kinetic energy available and of the rate of speed of the weight at the moment of impact. The supplementary conditions introduced by Captain Mimey are insufficient therefore, *a priori*, to secure the comparability of the resiliences obtained on two similar test-pieces. The authors have verified this on many occasions. They confine themselves, in the present instance, to giving the results of two series of determinations made, one on copper, the other on the special steel P. These two metals were selected in order to secure as complete as possible a degree of homogeneity in regard to internal structure.

The operations were conducted in the following manner: they had at their disposal two pendulum drop-weight machines geometrically similar, the falling weights of which were respectively 96.250 and 32.140 kg. To cause these two machines to work in the conditions required by similitude it was only necessary to give the first-mentioned pendulum a fall through an angle of 160 deg., and to allow the second to fall through an angle of 58 deg.

* "Note on Shock Tests;" *Revue d'Artillerie*, July, 1911.

There were then broken, on the larger machine (angle of fall 160 deg.) five test-bars measuring 30 by 30 by 160 (cylindrically notched half-way through with a notch 4 mm. in diameter) and forming a series of equal resilience. There were then selected, arbitrarily, the fragments of two of these test-bars, from which were made six test-bars of 10 by 10 by 53.3 (notched with a cylindrical notch 1.3 mm. in diameter, to one-half the thickness of the test-bar) taken from the larger bars in the manner shown in the sketch (Fig. 8). This mode of preparing the smaller test-bars (one, centrally from one of the pieces; the two others from nearer the surface of the other piece) was selected in order to be able to verify, simultaneously, the perfect homogeneity, in point of depth, of the metal tested. These six test-pieces were broken on the smaller pendulum drop-weight machine (angle of fall, 58 deg.).

In these conditions the results obtained on the copper and on the steel P were as follow:—

Metal Employed.	Description of Bars. Type.	Mark.	Individual Resiliences.	Average Resilience.	Average Divergence.	Average Relative Divergence.	Maximum Divergence.
			Kgm.			per cent.	
Copper	30×30 ×160	Cu I: 1	12.35	12.14	±0.27	2.2	12.61 to 11.83
		2	12.09				
		3	11.83				
		4	12.61				
		5	11.93				
	10×10 ×53.3	Cu I: 2-a	5.41	4.87	±0.18	3.7	5.41 to 4.76
		b	4.76				
		c	4.76				
		Cu I: 3-a	4.76				
		b	4.76				
		c	4.76				
Steel P	30×30 ×160	P I: 1	9.94	9.55	±0.38	4.0	9.94 to 9.46
		2	9.46				
		3	9.46				
		4	9.46				
		5	9.46				
	10×10 ×53.3	P I: 1-a	4.76	4.76	±0.0	0	0
		b	4.76				
		c	4.76				
		P I: 2-a	4.76				
		b	4.76				
		c	4.76				

This shows clearly: (1) that the internal homogeneity of the metal is satisfactory, seeing that the little test-pieces *a* and *b* behave precisely similar to the little test-pieces *c*; (2) that the resiliences given by the test-bars of 10 mm. by 10 mm. differ distinctly from the resiliences given by the test-bars of 30 mm. by 30 mm.

It is, therefore, justifiable to state that the law of similitude does not apply in the case of shock tests on notched bars.

Captain Mimey's conclusions are, however, applicable when a deformation is produced by shock—without proceeding as far as fracture—in bend tests without notches. For example, the deformations affect solely the volumes of the bars and may be, amongst each other, as the cube of homologous dimensions. But, as one of the present authors* has already observed, if the operation be carried as far as fracture, there would have to be introduced, in addition, the work absorbed by the separation of the two halves of the test-bar, work which may, at first sight, be regarded as proportional to the square of homologous dimensions. It would thus become a bi-terminal formula which would have to be introduced here, of the form.

$$\alpha x^2 + \beta x^3$$

to take accurate account of the phenomenon. In any case experiments undertaken with a view to verifying this mode of regarding the matter have not as yet yielded results sufficiently decisive to justify definite conclusions. They seem, indeed, to indicate that the complexity of the nature of the relation sought is even greater than the formula cited.

7. *Conclusions.*—The authors have been led, in the course of this investigation, to seek for a degree of accuracy that would obviously have no justification in practice, where it is, in most instances, only necessary to find out whether a metal is or is not brittle, and where a knowledge of the resilience is, within 1 per cent. or 2 per cent., of little importance.

It was, however, useful to carry out, at least once, groups of very uniform experiments in order to solve, with the greatest possible degree of accuracy, a whole host of unanswered questions which have accumulated during the last ten years or so, such, for example, as the influence, on the shock-test result, of the rate of impact, the weight of the drop-weight, &c.

Generally speaking, the authors believe they have shown clearly that the measurement of resilience is susceptible of a degree of accuracy similar to that obtained with current tests in the metallurgical laboratory, such, for instance, as those of tensile strength and hardness. Having attained to this degree of accuracy, the traditions on the strength of which attempts have been made to impose manipulative details not susceptible of technical justification have been seen to fade away.

They have likewise shown that shock tests on notched bars possess no direct relation with other common tests, and that they are infinitely more sensitive to the influence of certain peculiarities in the working of metals. If, as it now appears to be infinitely probable, if not indeed fully demonstrated, these influences act similarly on the way steel behaves in its various applications it would

* G. Charpy, "On Testing Metals by the Bending of Notched Bars"; *Mémoires de la Société des Ingénieurs Civils de France*, October, 1904.

certainly not be right to neglect methods of investigation capable of showing light upon them.

Being in possession of a homogeneous material they have been able, in all due safety, to study, by means of obtaining in each particular instance a small number of properly classified results (usually five), the influence of the various factors intervening in the shock test. They have thus been able to draw a series of conclusions which may briefly be summed up as follows :—

1. The shock-test machines of different types (pendulum drop-weights, vertical drop-weights, and rotary drop-weights) and of different dimensions employed by the authors give, in regard to resilience, results which are practically identical, given that uniform conditions are complied with as to the distance between supports and the radii of the supports in contact with the bar during testing. For the latter they have adopted a radius equal to that of the cylindrical portion of the notch (Copenhagen type) made in the corresponding test-bar (that is $r = 2$ mm. for bars 30 mm. by 30 mm. and 0.5 mm. for bars measuring 10 mm. by 10 mm.). They have also recognised the necessity of giving them the most careful machining and fitting in order to avoid the introduction of appreciable perturbations in the regularity of the experiments.

It is not therefore necessary, in order to obtain comparable results, to fix *a priori* on a special type of drop-weight ; it is enough to employ well-made and carefully calibrated machines of sizes within the limits of those usually employed. The correspondence between the scales of any two given machines, or the time factor in any one particular machine, can be calculated numerically by a calibrating experiment, which may be a simple bend test on an unnotched bar, the carrying out of which, under excellent conditions as to regularity, is easy.

2. The quantitative value of the resilience can only be formulated if, at the same time, the shape and dimensions of the bar and of the notch be given. The law which would permit of deductions being drawn, from the resilience as measured, for a given metal on bars of different dimensions, is not, as yet, known.

As was foreshadowed at the commencement of the present investigation, the authors have voluntarily confined themselves, in this research, to the elucidation of a certain number of points which the New York Congress confided to the attention of members of Committee 26. They have therefore taken into consideration only the shock-test machines ordinarily employed, the characteristics of which lie within comparatively narrow limits, and they have only sought to define accurately the conditions that require to be fulfilled in order to obtain uniform and comparative tests between them. This was obviously the first stage to surmount before carrying further any investigation on the subject.

They have not, therefore, viewed the problem from its wider theoretical aspects, although they recognise the powerful interest attaching to such a study. Their own research had, however, a purely practical object, to the exclusion, at least provisionally, of any speculative end.

It may finally be asked, What is the practical purport of such tests ? The authors propose to reply to this question in the future ; it is too delicate a one to be treated direct, or without long and well thought-out experiments. For the present they confine themselves to stating the problem and to emphasising the importance it possesses both to the producer and to the consumer.

APPENDIX.

Report of the Tests carried out on July 30, 1914, at the Laboratories of the Conservatoire National des Arts et Métiers, *on the requisition of* Mr. Charpy, *President of Committee No. 26 of the International Association for the Testing of Materials.*

Object of the Tests.—Comparative shock tests on notched steel bars.

Registered No. of the Investigations.—0–56.

Particulars of the Appliances employed.	Charpy Pendulum Machines.		Guillery Rotary Machines.		Vertical Drop-Weight.
	300 Kgm.	30 Kgm.	275 Kgm.	60 Kgm.	
Weight of tup (kilograms)	95.030	22.230	—	—	39.400
Radius of bearings : knife-edges (millimetres)	2.0	1.3	3.5	2.5	2.0
Radius of bearings : bearings (millimetres)	2.0	2.0	5.0 (approximate)	4.0 (approximate)	2.0
Angle of knife-edge (degrees)	30	30	45	45	30
Height of maximum fall from centre of gravity (metres)	3.179	1.333	—	—	4.0
Height of maximum fall of knife (metres)	3.879	1.438	—	—	4.0
Maximum rate of speed of knife (m/sec.)	9.637	5.519	8.858*	8.858*	8.858
Radius of centre of gravity (metres)	1.639	0.695	0	0	—
Radius of centre of impact (metres)	2.000	0.750	0.345	0.280	—

* Figures corresponding with a depth of fall of 4 m. The distances between supports is shown in each series of tests. All the bearings showed scale.

A.—Comparative Tests between the Different Heights of Fall on the Large Charpy Machine of 300 Kg.

Series.	Apparatus.	Distance apart of Supports.	Angle of Fall.	Height of Fall from Centre of Gravity.	Rate of Impact.	Bars: Type.	Bars: Section at Bottom of Notch.	Bars: Distinctive Mark.	No.	Angle of Rebound.	Work Absorbed: Total.	Work Absorbed: Per Cm_2 (Resilience).	Average Resilience.	Divergences: Maximum.	Divergences: Average.	Divergences: Relative Average.
		mm.	deg.	m.	m/sec.		cm_2.			deg.	kgm.	kgm/cm_2.	kgm/cm_2.	kgm.	kgm.	per cent.
1	Charpy 300-kgm. machine	120	160	3.179	9.637	1	4.5	J II.	11	114.5	76.85	17.08	17.27	1.12	0.34	2.0
									12	114.5	76.85	17.08				
									13	114.5	76.85	17.08				
									14	112.5	81.98	18.20				
									15	114.5	76.85	17.08				
2	Charpy 300-kgm. machine	120	65	0.946	5.257	1	4.5	J II.	6	14.5	84.68	18.82	16.88	3.46	0.97	5.7
									7	26.5	73.05	16.23				
									8	29.5	69.15	15.36				
									9	25.0	74.86	16.64				
									10	22.0	78.17	17.37				
3	Charpy 300-kgm. machine	120	160	3.179	9.637	1	4.5	P III.	6	129.5	41.67	9.26	9.31	0.24	0.08	0.1
									7	129.5	41.67	9.26				
									8	129.5	41.67	9.26				
									9	129.5	41.67	9.26				
									10	129.0	42.74	9.50				
4	Charpy 300-kgm. machine	120	45	0.480	3.738	1	4.5	P III.	1	17.0	38.55	8.57	9.14	1.20	0.33	3.6
									2	8.0	43.96	9.77				
									3	12.0	42.03	9.34				
									4	14.5	40.43	8.98				
									5	14.0	40.78	9.06				
5	Charpy 300-kgm. machine	120	160	3.179	9.637	1	4.5	A	10	123.5	55.05	12.23	11.62	1.27	0.32	2.8
									11	126.0	49.33	10.96				
									12	124.5	52.75	11.72				
									13	125.0	51.61	11.47				
									14	124.5	52.75	11.72				
6	Charpy 300-kgm. machine	120	55	0.699	4.519	1	4.5	A	3	25.0	51.38	11.42	12.52	1.76	0.46	3.8
									4	20.5	56.20	12.49				
									5	20.5	56.20	12.49				
									6	17.0	59.32	13.18				
									7	18.0	58.49	13.00				

B.—Comparative Tests between the Large and Small Charpy Pendulum Machines.

Series.	Apparatus.	Distance apart of Supports.	Angle of Fall.	Height of Fall from Centre of Gravity.	Rate of Impact.	Bars: Type.	Bars: Section at Bottom of Notch.	Bars: Distinctive Mark.	No.	Angle of Rebound.	Work Absorbed: Total.	Work Absorbed: Per Cm_2 (Resilience).	Average Resilience.	Divergences: Maximum.	Divergences: Average.	Divergences: Relative Average.
		mm.	deg.	m.	m/sec.		cm_2.			deg.	kgm.	kgm/cm_2.	kgm/cm_2.	kgm.	kgm.	per cent.
7	Charpy 300-kgm. machine	60	160	3.179	9.637	5	7.5	II.	4	141.0	23.36	20.76	21.07	0.78	0.37	1.8
									5	141.0	23.36	20.76				
									6	140.5	24.23	21.54				
									7	141.0	23.36	20.76				
									8	140.5	24.23	21.54				
8	Charpy 30-kgm. machine	60	156.36	1.333	5.519	5	7.5	II.	10	61.0	21.58	19.17	20.41	4.11	1.58	7.8
									11	44.0	25.23	22.42				
									12	44.5	25.13	22.34				
									13	58.0	22.28	19.80				
									14	65.0	20.61	18.31				

Remark : Metal described as identical with metal J (semi-hard nickel steel).

C.—Comparative Tests between the Large Charpy Pendulum Machine and the Vertical Drop-Test Machine.

Series.	Apparatus.	Distance apart of Supports.	Angle of Fall.	Height of Fall from Centre of Gravity.	Rate of Impact.	Bars: Type.	Bars: Section at Bottom of Notch.	Bars: Distinctive Mark.	No.	Angle of Rebound.	Work Absorbed: Total.	Work Absorbed: Per Cm_2 (Resilience).	Average Resilience.	Divergences: Maximum.	Divergences: Average.	Divergences: Relative Average.
		mm.	deg.	m.	m/sec.		cm_2.			deg.	kgm.	kgm/cm_2.	kgm/cm_2.	kgm.	kgm.	per cent.
1	Charpy 300-kgm. machine	120	160	3.179	9.637	1	4.5	J II.	11	114.5	76.85	17.08	17.27	1.12	0.34	2.0
									12	114.5	76.85	17.08				
									13	114.5	76.85	17.08				
									14	112.5	81.98	18.20				
									15	114.5	76.85	17.08				
2	Charpy 300-kgm. machine	120	65	0.946	5.257	1	4.5	J II.	6	14.5	84.68	18.82	16.88	3.46	0.97	5.7
									7	26.5	73.05	16.23				
									8	29.5	69.15	15.36				
									9	25.0	74.86	16.64				
									10	22.0	78.17	17.37				
														Remarks.		
9	Vertical drop-weight machine	120	—	1.800	5.942	1	4.5	J II.	1	—	70.92	15.76		Not broken.		
			—	1.800	5.942				2	—	70.92	15.76		,,		
			—	2.000	6.264				3	—	78.80	17.51		,,		
			—	2.050	6.342				4	—	80.77	17.95		Broken.		
			—	2.050	6.342				5	—	80.77	17.92		,,		

D.—Comparative Tests between the Charpy Pendulum Machine and the Guillery Rotary Machine.

Series.	Apparatus.	Distance apart of Supports.	Angle of Fall.	Height of Fall from Centre of Gravity.	Rate of Impact.	Bars: Type.	Bars: Section at Bottom of Notch.	Bars: Distinctive Mark.	No.	Angle of Rebound.	Work Absorbed: Total.	Work Absorbed: Per Cm_2 (Resilience).	Average Resilience.	Divergences: Maximum.	Divergences: Average.	Divergences: Relative Average.
		mm.	deg.	m.	m/sec.		cm_2.			deg.	kgm.	kgm/cm_2.	kgm/cm_2.	kgm.	kgm.	per cent.
10	Charpy 30-kgm. machine	40	156.36	1.333	5.519	3	0.7	J V.	6	95.0	12.77	18.24	18.55	0.77	0.25	1.3
									7	95.0	12.77	18.24				
									8	94.0	13.04	18.63				
									9	94.0	13.04	18.63				
									10	93.0	13.31	19.01				
11	Guillery 60-kgm. machine	40	—	—	8.858	3	0.7	J V.	1	—	13.0	18.6	18.4	0.9	0.34	1.9
									2	—	12.6	18.0				
									3	—	13.2	18.9				
									4	—	13.0	18.6				
									5	—	12.6	18.0				
12	Charpy 300-kgm. machine	120	160	3.179	9.637	1	4.5	J III.	1	112.5	81.93	18.21	18.78	1.43	0.45	2.4
									2	110.0	88.38	19.64				
									3	111.0	85.78	19.06				
									4	112.0	83.22	18.49				
									5	112.0	83.22	18.49				
13	Guillery 275-kgm. machine	120	—	—	8.858	1	4.5	J III.	6	—	98.0	21.78	20.45	2.00	0.71	3.5
									7	—	89.0	19.78				
									8	—	89.0	19.78				
									9	—	94.0	20.89				
									10	—	90.0	20.00				

Nature of the Samples submitted.—110 notched test-bars of five different types, of which the distinguishing marks and dimensions are given in the table to the right. These 110 test-bars were divided into 22 series of 5 bars each.

Distinctive Markings of the Bars.—Each of these bars bore a letter, a roman figure, and an arabic figure corresponding with the following descriptions furnished by Mr. Charpy :—

1. Letter indicative of the quality of the metal, namely :—
   A. Railway axle metal, annealed at 900 deg., air-quenched.
   J. Semi-hard nickel steel.
   K. Dead soft steel.
   P. Semi-hard chromium-nickel steel.
2. Roman figure, indicative of the bar from which test-pieces were cut.
3. Arabic figure, indicative of the order of distribution of the test-pieces in the bar from which they were prepared.

Description of the Types of Bars employed in the Official Investigation.

Dimensions of the Bars.	1.*	2.	3.	4.	5.
	mm.	mm.	mm.	mm.	mm.
Length of bars	160.0	53.3	53.3	53.3	80.0
Width	30.0	10.0	10.0	10.0	15.0
Thickness—					
Total	30.0	10.0	10.0	10.0	15.0
At bottom of notch	15.0	5.0	5.0	9.0	7.5
Notch—					
Shape	round	round	round	square	round
Dimensions	$r = 2$	$r = 0.66$	$r = 1$	1 × 1	$r = 2$
Mode of preparation	die	die	die	blunt saw	die
Section at bottom of notch	4.5 cm_2	0.5 cm_2	0.7 cm_2	0.9 cm_2	1.125cm_2

* Type described as "Copenhagen."

E.—COMPARATIVE TESTS BETWEEN BARS DIFFERENTLY NOTCHED.

Series.	Conditions of Test.					Bars.			Results.			Average Resilience.*	Divergences.		
	Apparatus.	Distance apart of Supports.	Angle of Fall.	Height of Fall from Centre of Gravity.	Rate of Impact.	Type.	Section at Bottom of Notch.	Distinctive Mark.	Angle of Rebound.	Work Absorbed			Maximum.	Average.	Relative Average.
										Total.	Per Cm_2 (Resilience).				
		mm.	deg.	m.	m/sec.		cm_2.		deg.	kgm.	kgm/cm_2.	kgm/cm_2	kgm.	kgm.	per cent.
									4 109.0	9.08	18.16				
									5 110.0	8.82	17.64				
14	Charpy 30-kgm. machine	40	156.36	1.333	5.519	2	0.5	K	6 106.0	9.85	19.70	18.78	2.58	0.95	0.5
									7 109.0	9.08	18.16				
									8 105.0	10.11	20.22				
									12 59.0	22.09	31.55				
									13 66.0	20.42	29.17				
15	Charpy 30-kgm. machine	40	156.36	1.333	5.519	3	0.7	K	14 60.5	21.74	31.06	30.78	2.38	0.73	2.4
									15 62.0	21.39	30.56				
									16 59.0	22.09	31.55				
									17 Bar not broken						
									18 ,,						
16	Charpy 30-kgm. machine	40	156.36	1.333	5.519	4	0.9	K	19 ,,			33.0	—	—	—
									20 ,,						
									21 ,,						
									1 140.0	2.25	4.50				
									2 140.0	2.25	4.50				
17	Charpy 30-kgm. machine	40	156.36	1.333	5.519	2	0.5	P III.	3 140.0	2.25	4.50	4.46	0.18	0.06	1.3
									4 140.0	2.25	4.50				
									5 140.5	2.16	4.32				
									6 130.0	4.16	5.94				
									7 130.0	4.16	5.94				
18	Charpy 30-kgm. machine	40	156.36	1.333	5.519	3	0.7	P III.	8 130.0	4.16	5.94	5.77	0.58	0.21	3.6
									9 131.0	3.96	5.66				
									10 132.0	3.75	5.36				
									1 140.0	2.25	4.50				
									2 140.0	2.25	4.50				
19	Charpy 30-kgm. machine	40	156.36	1.333	5.519	2	0.5	P IV.	3 140.5	2.16	4.32	4.36	0.34	0.11	2.5
									4 141.0	2.08	4.16				
									5 140.5	2.16	4.32				
									6 124.0	5.46	6.07				
									7 124.0	5.46	6.07				
20	Charpy 30-kgm. machine	40	156.36	1.333	5.519	4	0.9	P IV.	8 124.0	5.46	6.07	6.02	0.27	0.08	1.3
									9 124.0	5.46	6.07				
									10 125.0	5.23	5.81				
									1 120.0	6.37	12.74				
									2 122.0	5.91	11.82				
21	Charpy 30-kgm. machine	40	156.36	1.333	5.519	2	0.5	J IV.	3 121.5	6.02	12.04	12.14	0.92	0.34	2.8
									4 121.0	6.14	12.28				
									5 122.0	5.91	11.82				
									6 98.5	11.83	16.9				
									7 100.0	11.43	16.3				
22	Charpy 30-kgm. machine	40	156.36	1.333	5.519	3	0.7	J IV.	8 97.0	12.23	17.5	16.9	1.2	0.32	1.9
									9 96.0	11.96	17.1				
									10 99.0	11.70	16.7				

* By not taking into consideration the kinetic energy absorbed by the fragments, the figure for the average resilience for series "10" should be increased by about 0.02 kilogrammetre; for series "12" by about 3.6 kilogrammetres. For series "11" and "13" the figures for average resilience do not take into account the kinetic energy absorbed by the fragments.

Seen by the Director of the Testing Laboratories.
(Signed) F. CELLERIER.

The Superintendent of the Metals Section.
(Signed) SABATIER.

CERTIFIED COPY: Paris, July 30, 1914.

Object of the Tests.—The object of the tests was to obtain comparative results:—

A. At different heights of fall, on the large Charpy pendulum machine.

B. Between a large and a small Charpy machine.

C. Between the large pendulum machine and the vertical drop-weight machine.

D. Between pendulum machines and the rotary Guillery machine.

E. Between bars notched in different ways, tested by the small Charpy pendulum machine.

For the whole of these tests the series of bars intended to serve for comparative results were chosen haphazard.

RESULTS.

General Observations.—The tests were carried out on June 27, 1914, at the laboratory, by the laboratory staff. The temperature of the surrounding air was 20 deg. C.

In the tables (A to E) given on this and the preceding page the figures for the resiliences obtained with the Charpy pendulum machines take into account the kinetic energy absorbed by the fragments of the bars, on the assumption that the latter partake of the speed rate of the pendulum.

The figures obtained with the Guillery machine do not take this energy into account.

ELECTRIC STEEL MANUFACTURE IN DENMARK.—A company has been formed in Denmark, with a capital of 600,000 kronen, for the manufacture of steel from scrap, which is being smelted and refined and a little new iron added. It is said to be the same process which the Krupp works use for the manufacture of their best guns. To commence with, the new undertaking will confine its work to the production of smaller articles, machine parts, &c., but it is proposed to extend it, ere long, also to comprise heavy ingots by the Siemens-Martin furnaces, of which so far only one has been in use in Denmark—in the Burmeister and Wain establishment. Scrap is said to be available in sufficient quantities, but up to now it has principally been exported to Sweden. The new company, consequently, is fairly independent of foreign supplies, which is a very important point under the present circumstances. The undertaking is backed by several prominent men, and the installations will ultimately be on a large scale. The foundry building is two-storied, and has a length of over 100 m. Operations will commence probably by the end of November, and work is expected to be in full swing in the beginning of the new year.

LIGNITE DUST AS SUBSTITUTE FOR LYCOPODIUM.—Certain foundry models are dusted over with lycopodium powder to prevent the sand of the mould from sticking to the model. This lycopodium, we read in *Stahl und Eisen*, of July 26, 1917, was imported from Russia. When this source failed, a substitute was discovered in the finest dust from the drying rooms of lignite briquette works, which, so far, had been nothing but a nuisance. The fine particles, which contain a good deal of paraffin, behave like lycopodium when thrown on water, and this observation seems to have led to experiments on the utilisation of the dust.

GRAPHITE LUBRICATION.—In a paper contributed to the Journal of the American Society of Mechanical Engineers, Mr. C. H. Bierbaum states that in 1913 some 30,000 tons of graphite were used for lubrication purposes. He states that both natural and artificial graphites commonly contain impurities in the shape of very hard abrasive materials, the effect of which he demonstrated by using a wooden lap fixed on the end of a high-speed shaft and coated with the graphite to be tested. On applying a glass slip to this rapidly revolving lap the scratches produced by the impurities could be easily seen on examining them through the microscope, using oblique illumination. In the paper a number of micrographs are given showing the results obtained. With thoroughly purified graphite there is no abrasion. Mr. Bierbaum observes that to obtain permanent suspension of graphite in oils or the like the particles of graphite must be less than $\frac{1}{10000}$ in. in diameter, and the oil must be free from acid or from any tendency to form acids by turning rancid. He maintains that the use of these permanent suspensions of graphite is, however, undesirable, holding that with larger particles than are necessary for permanency of the suspension, the graphite is more effective as a lubricant. His view is that if the particles are large they will be caught and retained between the opposing surfaces of a bearing, should these approach near to each other owing to a failure of the oil film; whilst under similar conditions he asserts particles of the size necessary for forming a permanent colloidal suspension of the graphite would prove ineffective. The point, however, is obviously one to be settled by actual practical experience and not on a purely theoretical basis, and users of these colloidal suspensions do make the claim that, whatever the mechanism at work, their lubricated surfaces do, as a matter of fact, get loaded with graphite, notwithstanding the smallness of the particles.

CATALOGUES.

Punching Machines.—A well-assorted series of machines for punching, shearing and bending plates, I-girders and angles is shown in a catalogue from the Covington Machine Company, 14, Wall-street, New York. In all, 34 types are illustrated, some with electric motors attached. Every useful position and reach is provided.

Magnetos.—Messrs. Iliffe and Sons, Limited, Coventry, send a pamphlet summarising the efforts made in their motor cycle and car journals to stimulate the development of British manufacture of these little machines—efforts initiated before the war. The record is creditable, and an interesting proof of the public usefulness of trade journals.

Flow Recorder.—A catalogue received from the Cambridge Scientific Instrument Company, Limited, Cambridge, describes an instrument for measuring and recording the volume of air or gas flowing through a pipe. The pen is carried by a float which is actuated by the pressures from a Pitot tube. The record sheet gives a curve for 24 hours. The accuracy claimed is limited to the degree suitable for industrial purposes where the rate of flow exceeds 20 ft. per second. It may be used for coke ovens, blast-furnaces, gas producer plants, mine shafts and galleries, &c.

Haulage Gears.—A catalogue showing six types of haulage gear, all with electric drives, comes from the British Electric Plant Company, Alloa, Scotland. Four of these are for endless rope haulage; three with the wheels on horizontal shafts and one on a vertical shaft with worm drive. There are also a single drum and a main and tail haulage. The motors shown are three-phase, 750 r.p.m., the speed of the winding wheel being reduced as low as 11 r.p.m. The base plates are made in either cast iron or girders. Each machine is a complete unit, with power and gear ready to lay down and set to work.

Railway Excavating.—The Western Wheeled Scraper Company, Aurora, Illinois, U.S.A., send a pamphlet containing argument and figures to prove the economy of using an automatic air dump-car equipment in preference to a train of flat cars for what is termed "the execution of the operation of excavation." The machinery is not described, but it appears that the comparison is between two systems of loading, removing and dumping by using (1) two cars of an improved type, or (2) a train of 10 cars. The time lost when the equipments are shunted to allow trains to pass enters into the calculation. Six charts are used to bring out the meaning of the tables of figures. Railway engineers may find the pamphlet of interest.

Measuring Microscope.—The Cambridge Scientific Instrument Company, Limited, Cambridge, send a catalogue describing an instrument for workshop use for measuring lengths up to 1½ in., or 40 mm., and angles. The object is laid on a small table, which is fitted with aligning screws and V-blocks for holding rods or screws. The microscope is travelled by a micrometer screw with the usual graduated collar reading to 0.001 in. or 0.01 mm. The eyepiece has two hair lines at right angles, and the head carries a disc graduated in degrees of arc. In measuring, say, the angle of a V-thread, a hair-line is first put in line with one side of the V and the eyepiece then turned until the same hair lines with the opposite side, the difference between the two readings giving the angle. The disc has a vernier reading to 5 mm. of arc. The instrument may be used for measuring the diameter of Brinell hardness test indentations.

Coal Elevators.—Where stoking machines are used there is soon a demand for machinery to lift the coal and convey it to the hoppers; and it follows that such machinery should automatically supply the hoppers at the times and in the quantities required. The ashes may as well be removed by a similar process. This kind of machinery is very well explained and illustrated in a catalogue issued by Messrs. Edward Bennis and Co., Limited, of Little Hulton, Bolton, and 28, Victoria-street, London, S.W. 1. The plant is commonly found where a battery of boilers is in use, but it is also applicable, with economy as well as other advantages, to serve a single boiler. It is a kind of machinery requiring a higher degree of ingenuity to make than its rough aspect suggests. Owners and engineers will find this catalogue worth careful reading.

Spraying Mechanism.—The Spray Engineering Company, 93, Federal-street, Boston, Mass., U.S.A., has made a highly specialised study of spraying nozzles and apparatus and machines for applying these to a great variety of purposes. The nozzle is made in three pieces; a discharge piece and a piece for connecting to the source of supply—these are united by screw threads and are formed with a hollow chamber in which a loose piece is revolved by the flow of the liquid. The loose piece has exterior spirals or wings of various pitches to suit the purpose and material of the spray required. The various mechanisms are adapted to spraying condensing water to cool it; sprinklers for lawns, parks and general irrigation; painting and whitewashing; spraying asphalt in road-making; atomising liquids in chemical manufacture; scrubbing gases; and a hundred other purposes. A system of spray cleaning and cooling of pressure air for cooling electric generators has also been devised, and a special catalogue issued treats of this subject very completely and gives useful technical information. A spraying nozzle, with $\frac{1}{16}$ in. orifice and ¼-in. supply pipe sprays 0.14 gallon of water per minute at 5 lb. pressure and 0.47 gallon per minute at 50 lb. pressure. At the same pressures, respectively, a ¼-in. nozzle with 1¼-in. supply pipe will spray 12 gallons and 39 gallons per minute.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the Communicators are given in italics.

Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

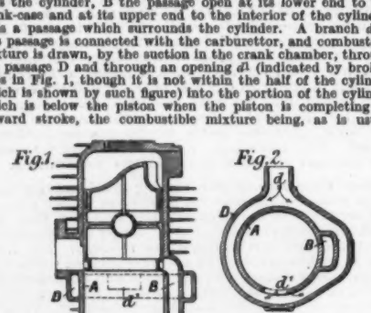
ELECTRICAL APPARATUS.

108,281. W. L. Gullette, and C. A. Vandervell and Co. Limited, London. Magnetos. (4 *Figs.*) March 30, 1917.—This invention relates to means for connecting the driving shaft of a magneto to the end-plate of the armature. The invention consists in pressing the brass end-plate of the armature, whilst hot, over the end of the shaft, which is placed in the dies while the end-plate is pressed, and which is shaped in such a manner that it can neither turn nor move longitudinally relatively to the brass end-plate after the connection has been effected. The end of the shaft *a* is machined with a projection *b* of dovetailed

longitudinal section, provided with two flat side surfaces *c*, and after having been placed into the dies the hot brass end-plate *d* is pressed thereon, whereby the latter is formed with a lug *e*, the inner surface of which is of dovetailed longitudinal section corresponding to the dovetailed portion of the shaft *a*, and has two flat surfaces *g* corresponding to the flat side surfaces *c* on the shaft. It will thus be seen that after the removal from the press, the brass end-plate will form a rigid positive connection with the shaft, the latter not being able to turn nor to move longitudinally within the lug formed on the end-plate. (*Accepted August* 9, 1917.)

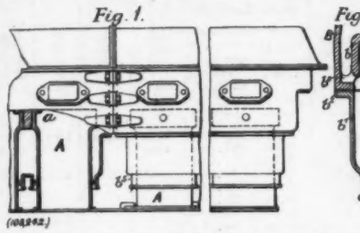
GAS ENGINES, PRODUCERS, HOLDERS, &c.

107,834. The D. F. and M. Engineering Company, Limited, Wolverhampton, and W. V. Ford, Wolverhampton. Internal-Combustion Engines. (3 *Figs.*) July 27, 1916.—This invention has for its objects to utilise the heat of a cylinder of a two-stroke internal-combustion engine to raise the temperature of combustible mixture on its way from the carburettor to the crank chamber, and to avoid or minimise "blow-back" of combustible mixture into the atmosphere. A is the cylinder, B the passage open at its lower end to the crank-case and at its upper end to the interior of the cylinder. D is a passage which surrounds the cylinder. A branch *d* of this passage is connected with the carburettor, and combustible mixture is drawn, by the suction in the crank chamber, through the passage D and through an opening d^1 (indicated by broken lines in Fig. 1, though it is not within the half of the cylinder which is shown by such figure) into the portion of the cylinder which is below the piston when the piston is completing its upward stroke, the combustible mixture being, as is usual,



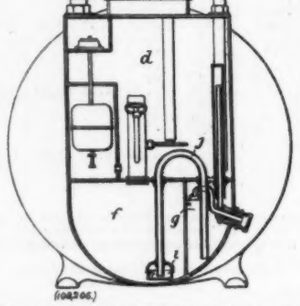
compressed within the crank chamber during the downward stroke of the piston, and the compressed mixture being admitted to the upper side of the piston to be compressed by the up-stroke of the piston and then exploded. The combustible mixture flowing through the branch *d* divides as it enters the passage D, the two portions flowing together through the opening d^1 into the cylinder. The lower edge of the opening d^1 is some distance above the bottom of the passage D, to ensure that in case of flooding the carburettor, for starting the engine, liquid fuel will not flow through such opening and fall into the bottom of the crank chamber. The inner side of the passage D is constituted by the wall of the cylinder, and thus the combustible mixture which passes through the passage D is highly heated by the heat from the cylinder. (*Accepted July* 25, 1917.)

108,242. Wolseley Motors, Limited, A. A. Remington, and J. D. Pitt, Birmingham. Internal-Combustion Engines. (4 *Figs.*) October 12, 1916.—This invention relates to the type of multi-cylinder internal-combustion engines in which independently constructed cylinders formed with integral heads are fixed to a common cooling jacket, and in which the cooling water is in direct contact with the portions of the cylinders within which the pistons travel. The combustion chamber *a* of each cylinder A is formed to an enlarged diameter, as shown, to give additional space for seating the valves within the head of the cylinder, and the portion of enlarged diameter is screwed into the inner wall *b* of the upper portion B of the water jacket. The upper portion of the water jacket extends to about the bottom or inner end of the portion of enlarged diameter of the cylinder, and below such point the jacket extends as a skirt b^1, which is conveniently fixed by means of a flange b^2 to the upper portion of the jacket. The upper and lower portions of the jacket are always in communication with one another, such as through openings b^3. The cooling water which enters the lower portion of the jacket is in contact with the exterior surface of the portion a^2 of the cylinder within which the piston travels. The lower end of the skirt b^1 is shown to be brought nearer to the cylinder wall than is the upper portion, and to be packed by means of a suitable packing ring, which is inserted within a groove formed within a collar which surrounds the portion a^2 of the cylinder, thereby preventing leakage from the jacket between



the lower end of the skirt and the cylinder. There is, preferably, a common skirt for each group of cylinders (see Fig. 1), the lower end of this skirt being formed with a number of secondary skirts or sleeves b^5 which surround the cylinders respectively, and are packed in the manner described, and shown more particularly by Fig. 2. (*Accepted August* 9, 1917.)

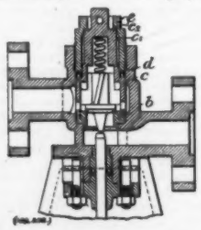
108,206. J. Wilson, and Parkinson and W. and B. Cowan, Limited, London. Wet Gas Meters. (2 *Figs.*) July 31, 1916.—This invention relates to wet meters for gas of the type having an upright return conduit for maintaining a double seal against the escape of gas from a compartment in which the junction of the two limbs of the conduit may be carried above the level to which liquid may rise in the compartment. The invention consists in a sealing device for a wet meter for gas comprising an upright return conduit *j* having one extremity in the sealed compartment *f* and the other extremity exterior



thereto, in which the first-mentioned extremity dips into a small, open-topped receptacle *i* at the bottom of the compartment *f*, said receptacle having an orifice whereby it is refilled after the level of the surrounding liquid has fallen to its upper edge, so that the conduit may be re-sealed after having been emptied of liquid by an excess of pressure. The return conduit *j* has its connecting or semicircular portions positioned in an upper watering compartment *d*, and one extremity opens into a water outlet siphon compartment *g*, preferably below the level of the inside end of the siphon, while the other extremity opens to the atmosphere adjacent to the outside end of the siphon pipe. (*Accepted August* 9, 1917.)

HYDRAULIC MACHINERY.

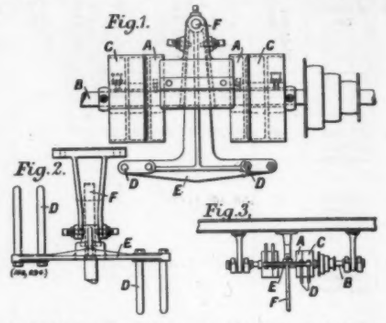
108,292. H. Crowe, Saltburn-by-the-Sea. Hydraulic Valve Seatings. (1 *Fig.*) July 23, 1916.—This invention relates to the seating of hydraulic operating valves controlling single and double-acting cylinders, and pertains more particularly to that type of valve in which a cage is employed for holding a loose valve seat in position. The invention consists in an improved form of construction of such a cage, with a view to employing a valve body, screwed cover and packing leather of less size than would ordinarily have to be employed, and generally



making a more efficient and compact arrangement of parts. The valve body or casing is made to receive a loose valve seat *b*, which is easily removable, and is held in position by a special form of cage *c*, having the upper portion c^1 reduced in diameter so as to form a shoulder wide enough to receive the "U" packing leather *d*, which forms the hydraulic joint between the valve casing and the outside of the cage *c*. The uppermost portion c^1 of the cage is pressed down on to the valve seat *b* by means of the top cover *e*, which is either screwed into the valve body or held down by bolts, and bears upon the shoulder c^2 of the cage. (*Accepted August* 9, 1917.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

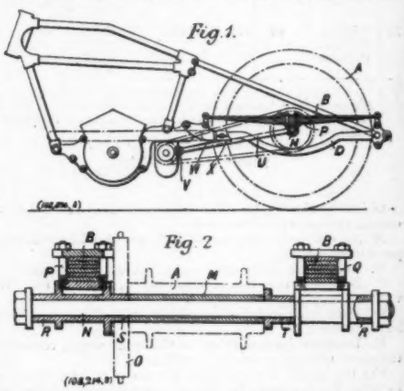
108,094. A. Herbert, Burford, Oxfordshire, and J. Milburn, Coventry. Metal-working Machine Tools. (3 *Figs.*) December 4, 1916.—This invention relates to belt-striking gear, particularly for machine tools, of the kind in which a shaft is driven by straight and crossed belts in either direction through the medium of fast and loose pulleys. The invention comprises the combination of two fast pulleys located on a shaft symmetrically between two loose pulleys and pivoted striking fork, adapted to move two belts simultaneously so that one belt is moved from one of the loose pulleys to its adjacent fast pulleys or *vice versa*, while the other belt is moved across the face of the other loose pulley. Fast pulleys A are rigidly connected to a driving shaft B for a machine tool, which shaft B also carries loose pulleys C which are wider than the fast pulleys. D are pins forming striking forks and carried on a rocking bracket E,



which is rigidly connected to a rotatable rod F. If the bracket E is rocked in either direction from a central position, in which each of the belts is on a loose pulley C, a belt in one of the forks is moved on to its fast pulley, while the belt in the other fork is moved idly, as it is only caused to move across the face of its loose pulley. Thus if one of the belts is crossed the direction of rotation of a driven shaft can be readily reversed, or its rotation can be stopped by moving the rocking bracket E into its central position. (*Accepted August* 1, 1917.)

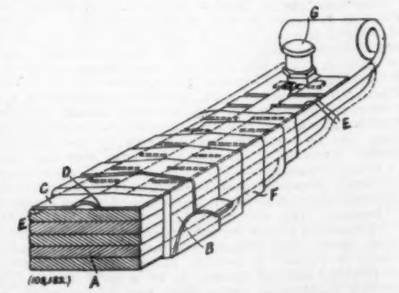
MOTOR ROAD VEHICLES.

108,214. The Coventry Acme Motor Company, Limited, and W. J. Robb, Earlsdon, Coventry. Motor-Cycle Frames. (3 *Figs.*) August 7, 1916.—This invention, which is specially suited to a chain-driven motor cycle, relates to mounting the rear wheel in a frame of the kind which comprises the combination of two rear-side members D, rigid with the main frame and extending one on each side to the rear of the back wheel A, leaf springs B on the side members to support the back wheel spindle, radius rods U to connect the spindle with the frame, and a spindle-bearing block P or Q clamped on each spring. The wheel A is carried on a sleeve M (Fig. 2), supported on a



bolt N, and is connected to the sprocket O. The bearing blocks P and Q support the bolt N. An outer extension R, on each bearing block, serves as a pivot for one of the radius rods U. An inner extension S on the bearing block P supports the sprocket when it is detached from the back wheel for the removal of the latter. A distance-piece T is provided between the wheel hub and the bearing block Q. Each radius rod U (Fig. 1) is pivoted at one end on one of the extensions R of the bearing blocks P and Q, and at the other end is pivoted to a pin V, carried on an arm W adjustably clamped at X to a bottom rail-member D. (*Accepted August* 9, 1917.)

108,182. R. W. Maudslay, Coventry. Lubricating Laminated Springs. (1 *Fig.*) July 24, 1916.—This invention relates to apparatus for lubricating laminated springs such as are used on road vehicles. An oil distributing metal plate C, provided with a channel D and oil-discharging slits E, is bound on to a



laminated spring A by absorbent felt B and by a tape F, which latter also forms an oil-tight wrapping. The slits E open into the channel D so that the oil can escape laterally from the channel, and at the same time the slits increase the resiliency of the plate C. G is an oil cup. (*Accepted August* 9, 1917.)